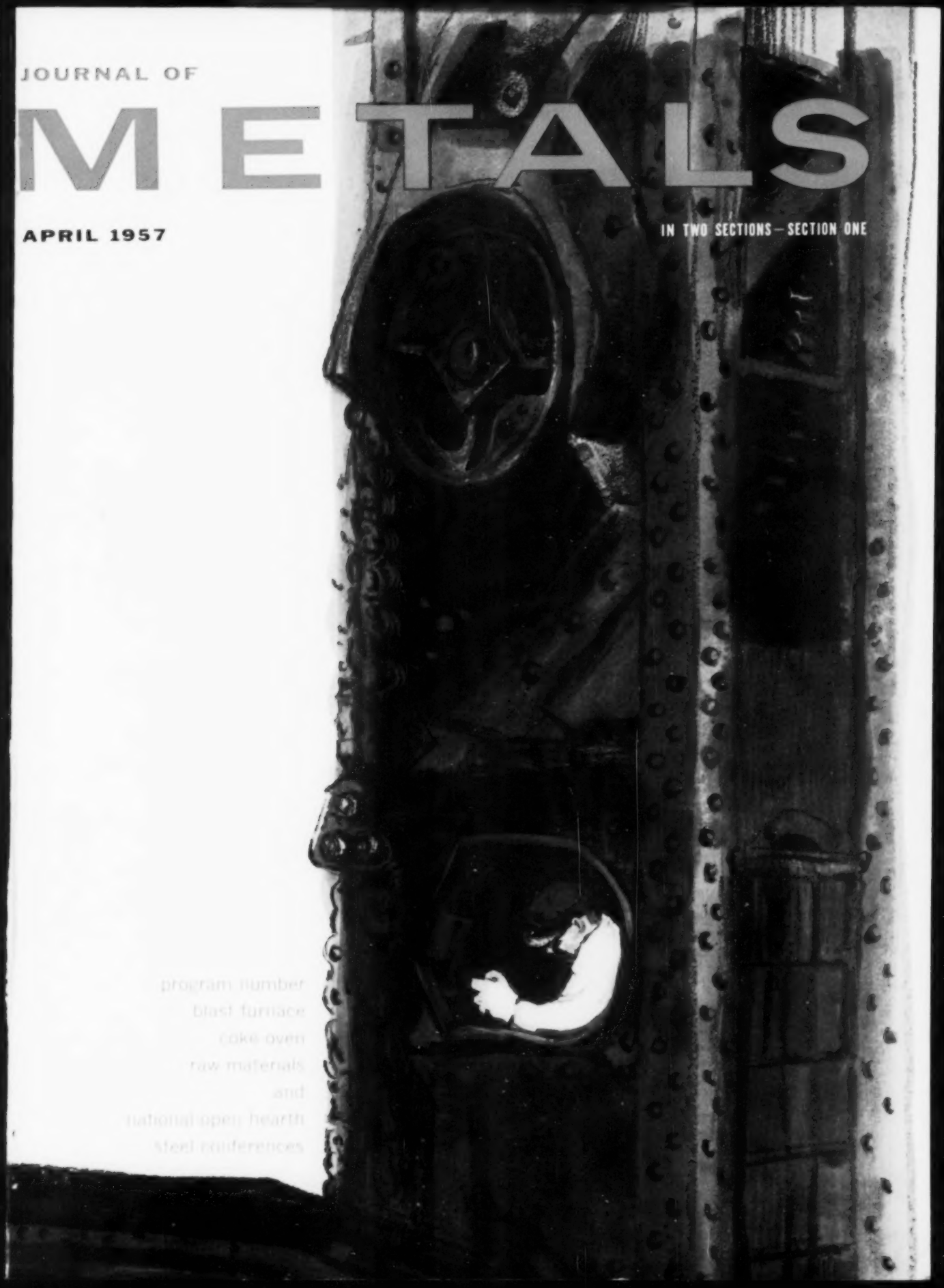
JOURNAL OF

METALS

APRIL 1957

IN TWO SECTIONS—SECTION ONE



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VOL. 9, NO. 4

APRIL 1957

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1—Magazine 2—Transactions Section

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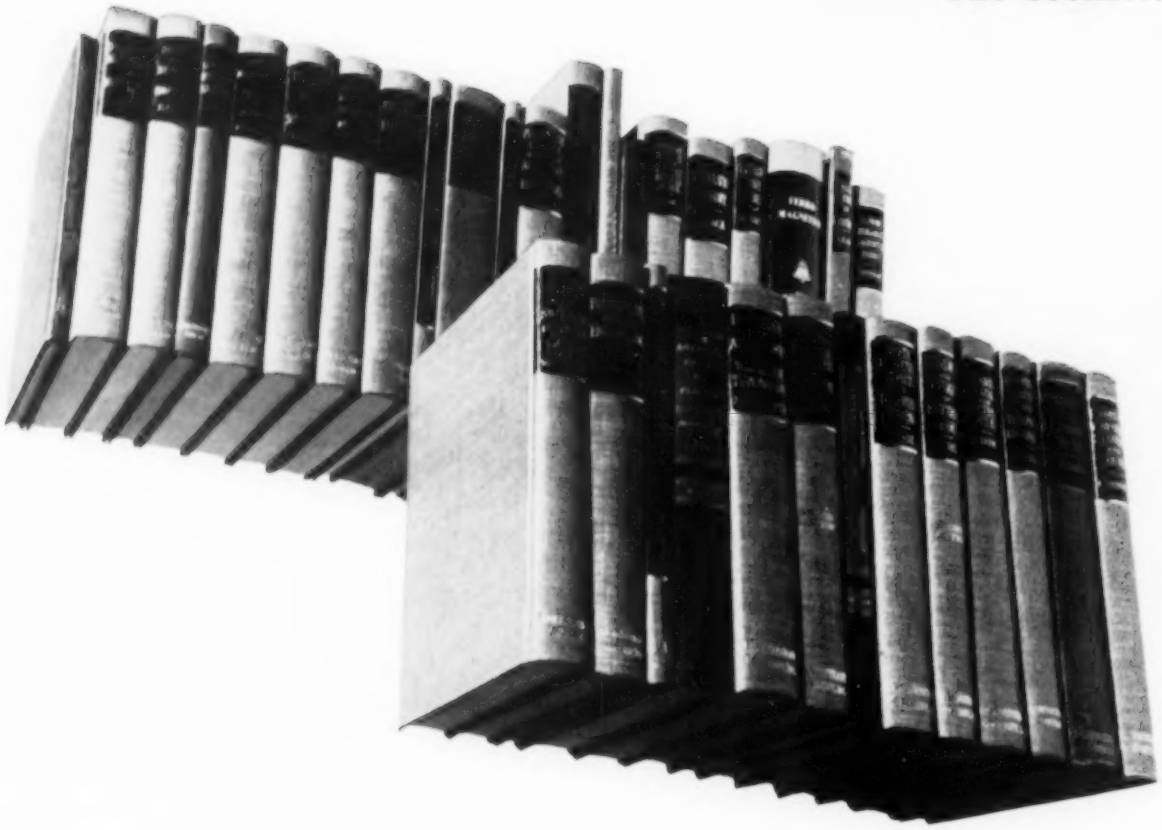

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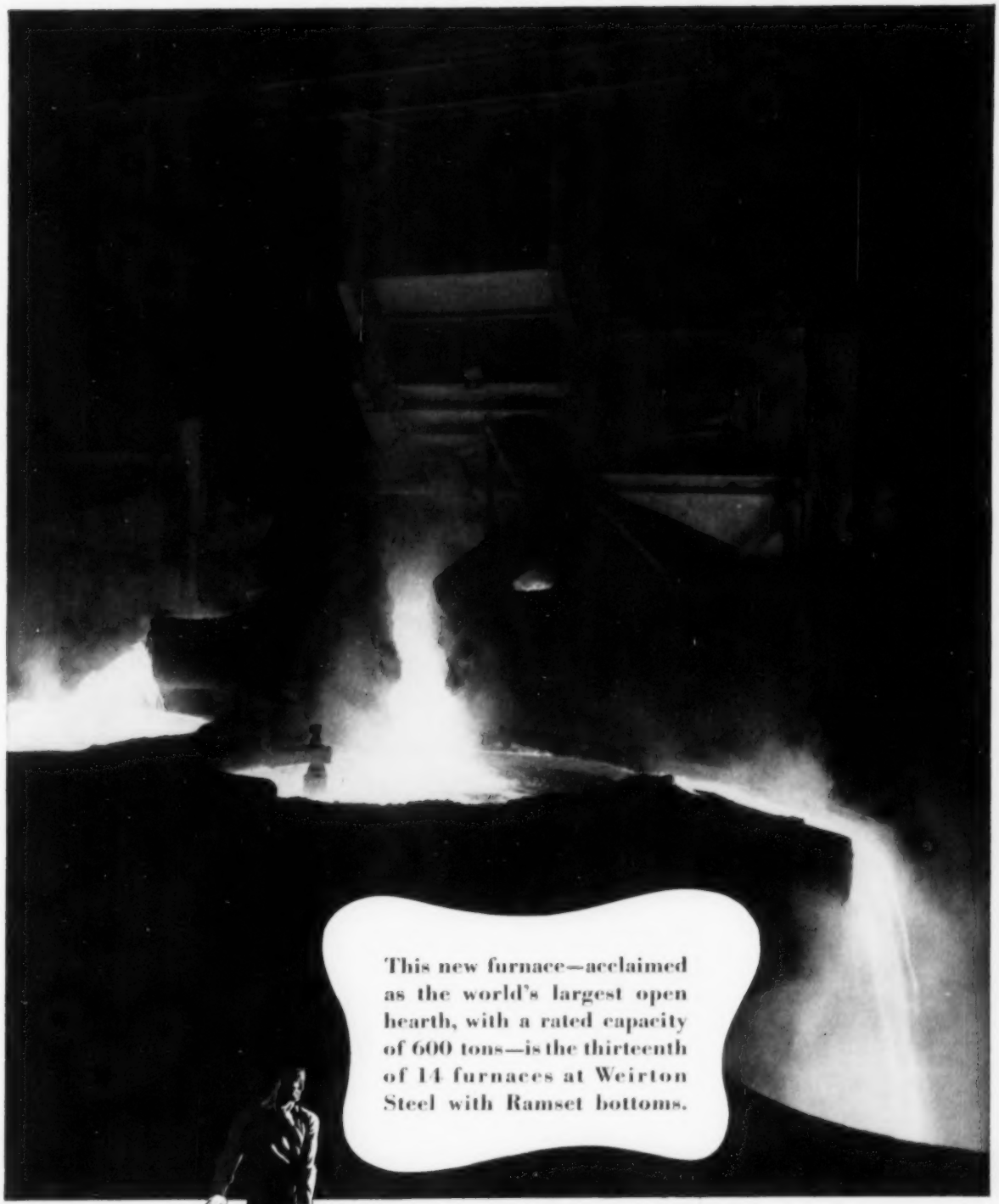
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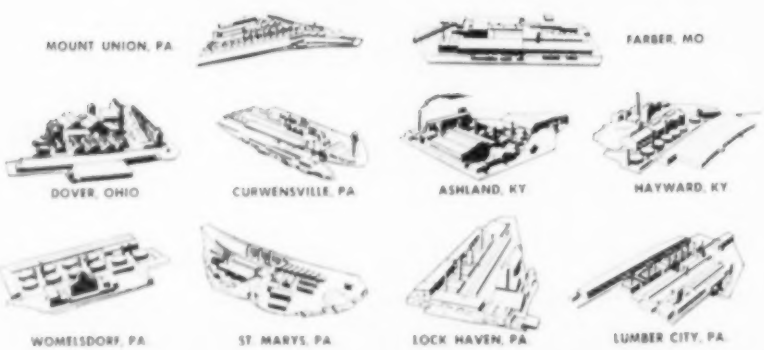

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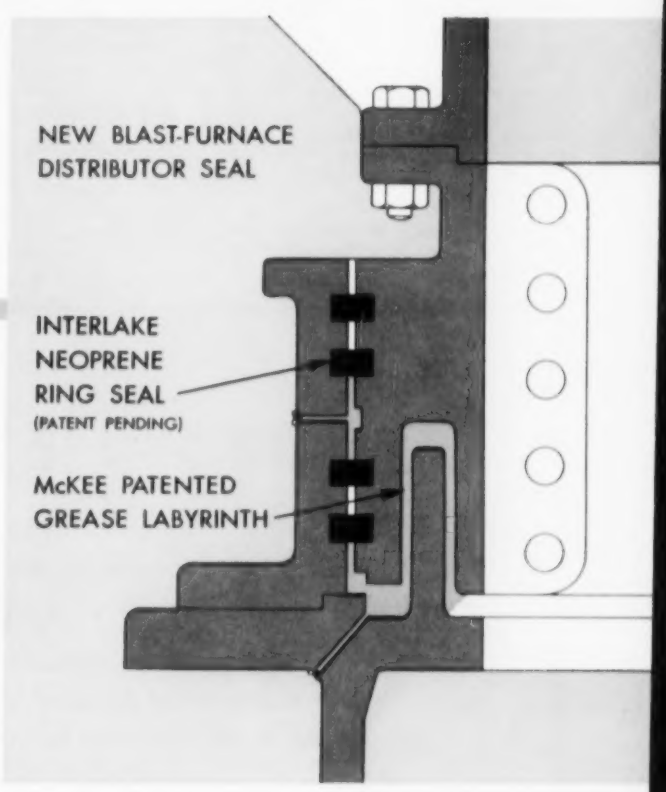

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ASTM Standards on Zinc-Coated Iron and Steel Products, *American Society for Testing Materials*, 134 pp., $2.25, 1956.—Compiled under the sponsorship of Committee A-5 on Corrosion of Iron and Steel, this booklet incorporates standards, tentative specifications and methods of test pertaining to metallic coated iron and steel products.

An Encyclopedia of the Iron and Steel Industry, compiled by A. K. Osborne, *Philosophical Library Inc.*, 558 pp., $25.00, 1956.—This is a comprehensive reference to the iron and steel industry and those closely allied to it, providing concise descriptions of the materials, plant, tools, processes, and technical terms employed. Though its scope precludes technical depth, even the specialist will find it useful as a guide to subjects bordering on his own.

Metallurgy and Fuels, ed. by H. M. Finniston and J. P. Howe, *McGraw-Hill Book Co. Inc.*, 785 pp., $21.00, 1956.—This volume, number five in the Progress in Nuclear Energy Series, is a collection of papers on the problem of the reactor—the production of serviceable fuel elements, coolants, and moderators. In addition to studies of the elements, sections on the effects of irradiation and solid state physics are also included.

F B I Register 1957, *Kelly's Directories Ltd.* and *Iliffe & Sons Ltd.*, 1124 pp., approx. $6.00, 1956.—Published for the Federation of British Industries, the 1957 register is a comprehensive guide to a cross section of British industries, listing the products and services of more than 7000 member firms. It features French, German, and Spanish glossaries, alphabetical listings of companies, with their addresses, products and services, a trade association index, a brand and trade name glossary, and trademark reproductions.

ASM Review of Metal Literature, Vol. 12, ed. by M. R. Hyslop, *American Society for Metals*, 7301 Euclid Ave., Cleveland, 732 pp., $15.00, 1956.—This is the twelfth annual compilation of references from *Metals Review*, grouped on the basis of process or property.

The Embrittlement of Metals, by B. R. Queneau, *The American Society for Metals*, 7301 Euclid Ave., Cleveland, 90 pp., $3.00, 1956.—This is a collection of four lectures, the first of which is a general treatment of the subject. Others deal with brittleness in carbon alloy, hardened, and stainless steels. A bibliography of 215 references compiled by G. A. Ratz is included.

Photoconductivity Conference, ed. by R. G. Breckenridge, B. R. Russell, and E. E. Hahn, *John Wiley & Sons, Inc.*, 640 pp., $13.50, 1956—Thirty papers by 45 authorities on solid state physics discuss basic and phenomenological theory, interpretation of photoconduction phenomena, and the latest data on the properties of photoconducting materials.

Materials of Engineering, by C. A. Keyser, *Prentice-Hall Inc.*, 482 pp., $8.00, 1956—This is a discussion of the properties, fabrication, and testing of ordinary materials used in engineering. It is subdivided into sections on metallic, non-metallic, and organic materials. Illustrated.

Defects and Failures of Metals, by E. P. Polushkin, *Elsevier Publishing Co.*, 392 pp., $12.50, 1956.—This volume is concerned with the failures and defects of whole field metals and their alloys. Their origin, causes, and elimination are described, and wherever applicable the close correlation between types of failure is indicated. Extensive references accompany each chapter.

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Oxidation Resistant Silicon Aluminium Steels, by E. A. Brandes, Special Report No. 2, *Fulmer Research Institute Ltd.,* Stoke Poges, Buckinghamshire, Eng., 40 pp., $1.50, 1956.—These steels, intended for alternative application where highly alloyed steels are now employed, are described with respect to preparation, oxidation and corrosion tests, mechanical properties, weldability, and practical trials.

Steel Foundry Dust Control and Ventilation, *British Steel Castings Research Assn.,* Sheffield 10, Eng., 98 pp., $6.00, 1956.—The technical papers published herein, presented at a 1955 conference, deal with dust control and extraction, exhaust systems, dust collectors, and foundry heating and ventilation.

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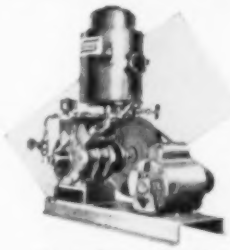

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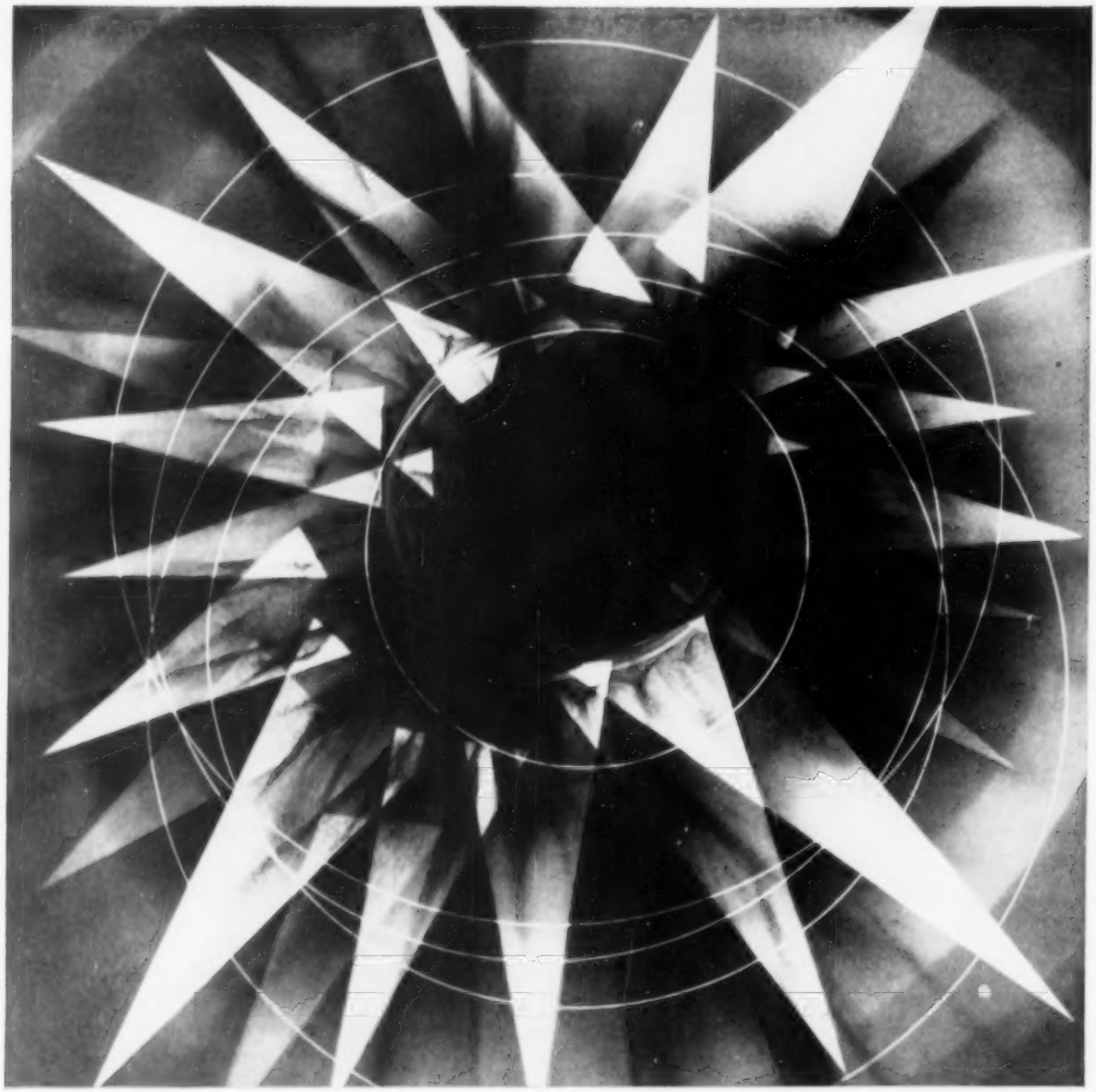

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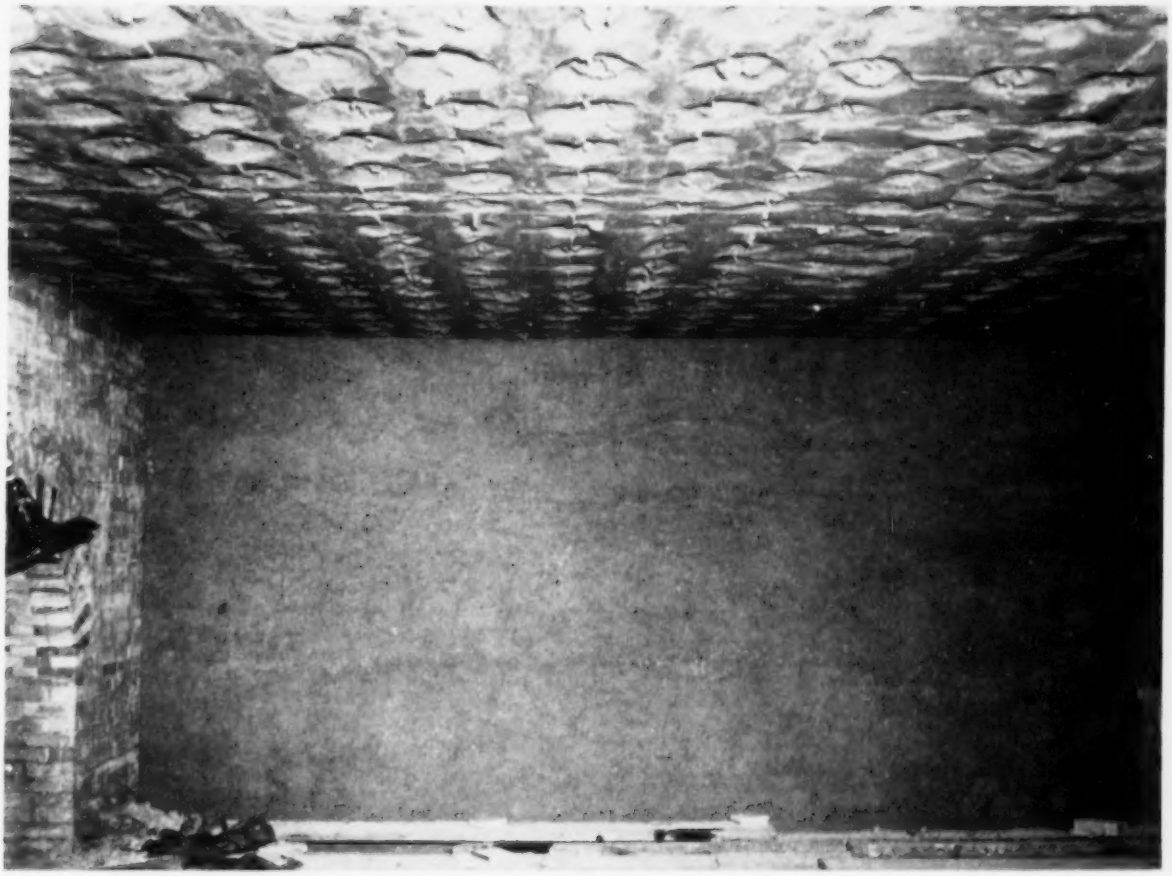

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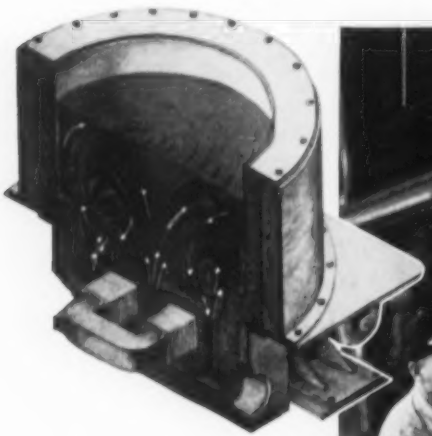

Cross section of AJAX-TAMA-WYATT twin coil induction furnace such as used at the Torrance Brass Foundry. Heat is produced within the molten metal in the secondary channels and conveyed throughout the melt by electromagnetic circulation, resulting in minimum metal losses and high uniformity of alloy. Temperature is automatically controlled.

(Photograph courtesy of Long Beach Press-Telegram, Long Beach, Cal.)

The furnace pictured here is melting aluminum bronze at the *Torrance Brass Foundry, Torrance, Cal.*, operating at a temperature of 2400 F, for the production of high strength centrifugal castings. This unit is rated 100 kw. Note also the clean, smokeless operation as shown in the unretouched photograph.

AJAX

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INDUCTION MELTING FURNACES

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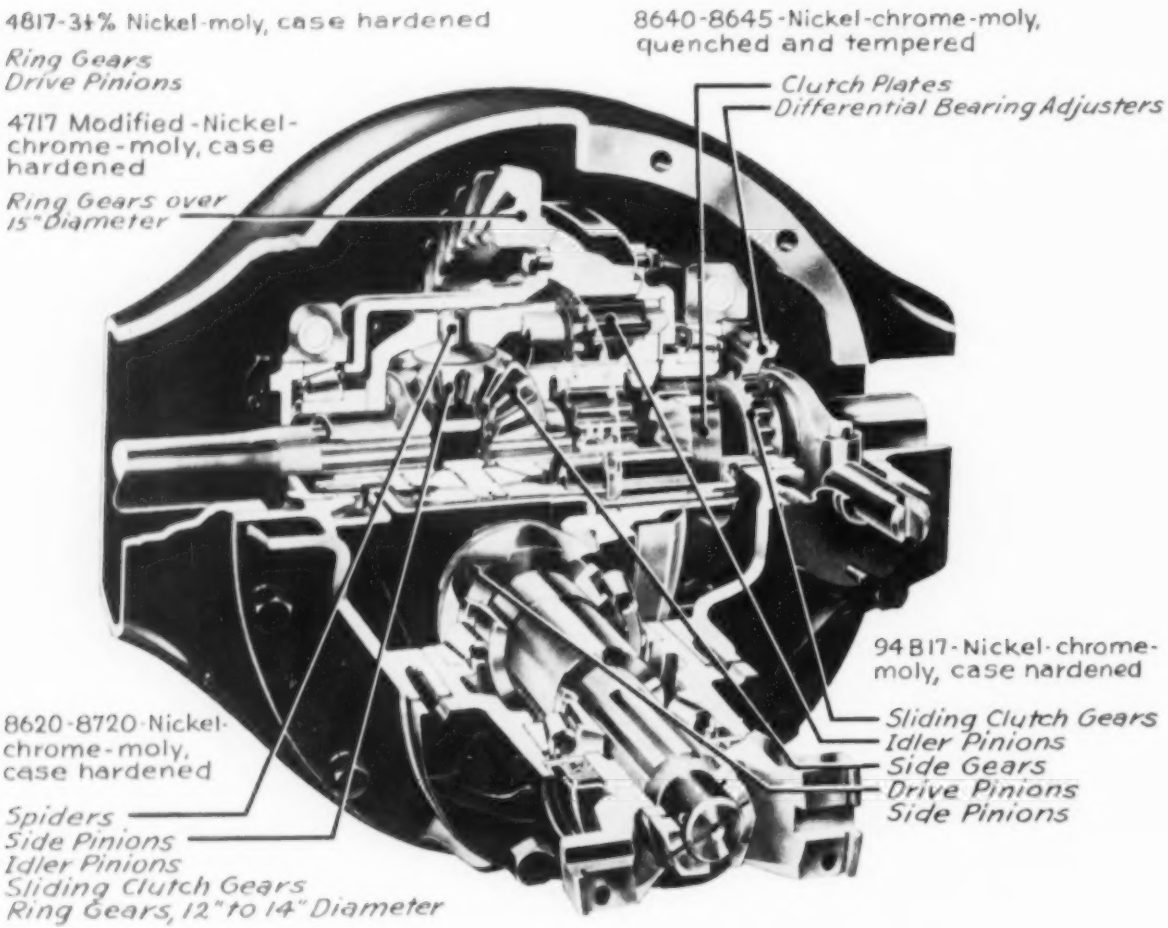

Slip this ad under your blotter as a reminder.

It illustrates how a manufacturer — you perhaps — can take advantage of the versatility and true engineering economy of nickel alloy steels.

The picture is a view of an Eaton heavy-duty, 2-speed truck axle. It shows the steels Eaton Manufacturing Company of Cleveland, Ohio, uses to make the many axle types rugged and durable . . . hence economical.

Notice how carefully Eaton selected the steels. Each just right for the part.

Leading manufacturers and users of *super-heavy-duty* vehicles know that it does not pay to skimp on materials in parts such as rear axle drive pinions and ring gears. Use of lower alloyed substitute steels would result in frequent failures and replacements, time lost in the shop, more parts sent to the scrap pile, and more steel and alloys eventually consumed. True economy and efficiency means specifying the most durable and dependable materials for vital truck parts.

Moral of the story: what nickel alloy steels do for Eaton, they can do for you. The address below is another reminder: Inco will provide all possible assistance in selecting the most suitable steels for *your* service.

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Use of Oxygen in Steel Industry Grows

Since the wartime development of low-cost tonnage oxygen producing techniques, a veritable revolution seems to be taking place in the steel industry with pure oxygen or oxygen enrichment used in the blast furnace and in steelmaking furnaces. This trend may be more evident in the U.K. Last August that country's first tonnage (100 tpd) oxygen plant was inaugurated at the Margam works of the Steel Co. of Wales Ltd. At the same mill, British Oxygen Co. Ltd. is now building a second plant of 200 tpd capacity. In addition, two 200 tpd and two 100 tpd oxygen plants are being built at other British steel mills. Cost of these plants is about £ 10 per ton of oxygen per year.

Increase, LD Oxygen Converter Installations

Kaiser Steel Corp., as part of its $113 million expansion program, is installing two 65-ton oxygen lance converters at Fontana, Calif. In the Netherlands at Ijmuiden, the Royal Dutch Blast Furnaces and Steel Works is to build a 300,000 ton oxygen converter plant which should be in operation next year. And in India a 1-million ton steel works is being built at Rourkela (Orissa) by German concerns for Hindustan Steel Ltd. Plans call for installation of three LD oxygen converters to produce 750,000 tons of steel per year.

Kaiser Granted Rights for Open-Hearth, Lance Process

Kaiser Engineers Div. of Henry J. Kaiser Co. has been granted the rights to make, use, sell, and sublicense the oxygen lance for open hearth steelmaking throughout the world except Europe. The oxygen lance technique was developed at the Abbey Works of the Steel Co. of Wales Ltd. and is described on page 274 of the February Issue of the JOURNAL OF METALS.

Rotating Oxygen Converters to be Installed

At Oxelosund on the central Swedish coast, a new steelmaking plant is to be built. It will comprise two 80-ton Kal-Do rotating oxygen converters of combined annual capacity of 475,000 tons. Iron from existing blast furnaces is expected to be used. This is the first sale of a license for the new Kal-Do process developed by Stora Kopparbergs Bergslags in Sweden. The process is to be described in detail in a forthcoming issue of the JOURNAL OF METALS.

Open Hearths Getting Larger

Steelmakers are turning to larger and more modern open hearth furnaces for greater unit productivity. Ten years ago there were only 30 furnaces capable of heats of more than 225 tons, while today there are 204 such open hearths in the U. S. Recently, the largest open hearth furnace in the history of steelmaking started operation at the plant of Weirton Steel Co. The new furnace, with a rated capacity of 600 tons per heat, was built by Loftus Engineering Co. of Pittsburgh. It has outer wall dimensions of 26 ft 9 in. by 108 ft 6 in. with a hearth area of 1485 sq ft; it can be fired with oil or tar. In addition to the 600-ton giant, Weirton's open hearth shop consists of two furnaces rated at 550 tons, one at 500 tons, five at 450 tons, and five at 275 tons. It is the largest single open hearth shop in the world.

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Ground Fire Clay. A smooth, high quality, plastic fire clay with low shrinkage for laying up fire brick and other fire clay refractories.

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Carbon. Chemically bonded Carbon Chem-Brix assure longer service and less spalling, especially for iron and Bessemer steel ladles.

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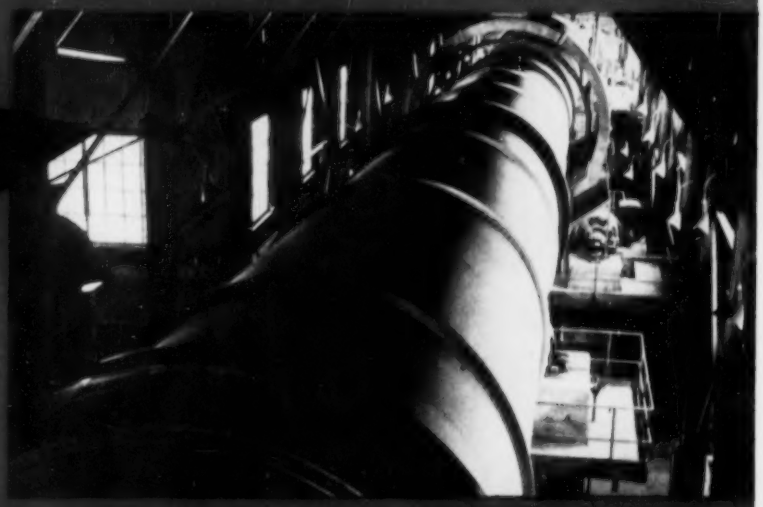

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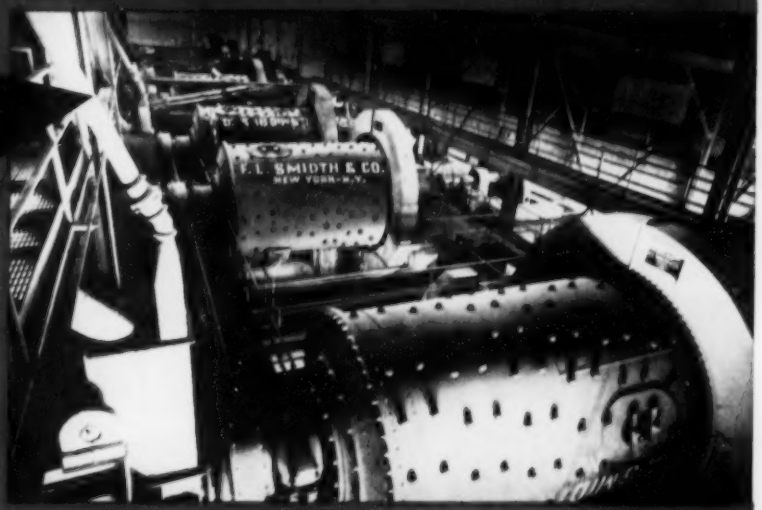

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Annual Capacity of Blast

Company	No. of Stacks	Total Annual Capacity, Net Tons*
Alan Wood Steel Co.	2	454,800
Armco Steel Corp.	6	2,104,000
†Sheffield Div.	1	420,000
Barium Steel Corp.		
†Phoenix Iron & Steel Co.	1	200,000
Berkman Co., Louis	1	136,800
Bethlehem Steel Co.	33	‡12,830,000
Colorado Fuel & Iron Corp.	7	1,425,040
Crucible Steel Co. of America	3	895,000
Detroit Steel Corp.	2	768,700
Eastern Gas & Fuel Assoc.	1	195,000
Ford Motor Co.	3	1,165,980
Granite City Steel Co.	2	675,000
Inland Steel Co.	8	3,011,200
Interlake Iron Corp.	7	1,630,000
International Harvester Co.	3	808,000
Jackson Steel & Iron Co.	1	95,000
Jones & Laughlin Steel Corp.	13	4,807,000
Kaiser Steel Corp.	3	1,314,000
Lavino & Co., E. J.	3	§184,000
Lone Star Steel Co.	1	385,000
McLouth Steel Corp.	1	483,500
Merritt-Chapman & Scott Corp.:		
†Tennessee Products & Chemical Corp.	3	217,740

* Figures represent net blast furnace capacity after average deduction of 5.2 pct was made by producers for operating time lost because of rebuilding, relining, and repairs. † Indicates subsidiary. ‡ Includes 216,000 tons ferroalloys capacity. § Ferromanganese only.

Annual Steel Capacity (Ingots and

Company	Open Hearth		Bessemer		Electric and Crucible		Total Annual Capacity, Net Tons†
	No.	Annual Capacity, Net Tons†	No.	Annual Capacity, Net Tons†	No.	Annual Capacity, Net Tons†	
Acme-Newport Steel Co.	7	325,000			3	283,000	608,000
Alan Wood Steel Co.	9	800,000					800,000
Alco Products Inc.	3	103,000			1	2,160	105,160
Allegheny Ludlum Steel Corp.	5	312,000			30	552,200	864,200
American Compressed Steel Corp.					1	21,600	21,600
Armco Steel Corp.	27	3,381,000			9	469,000	3,850,000
‡Sheffield Div.	13	1,380,000			5	720,000	2,100,000
Atlantic Steel Co.	3	124,000			2	276,000	400,000
Babcock & Wilcox Co.					4	229,450	229,450
Baldwin-Lima-Hamilton Corp.	5	169,920			‖1	40	169,960
Barium Steel Corp.:							
‡Industrial Forge & Steel Co.	2	48,600					48,600
‡Phoenix Iron & Steel Co.	11	806,760			1	40,000	846,760
Berkman Co.,							
Louis Ohio River Steel Div.	4	136,080				136,080	136,080
Bethlehem Steel Corp.:							
‡Bethlehem Steel Co.	125	18,934,000	3	336,000	6	230,000	19,500,000
‡Bethlehem Pacific Coast Steel Corp.	10	522,000			3	478,000	1,000,000
Borg-Warner Corp.:							
‡Ingersoll Steel Div.					4	64,000	64,000
‡Ingersoll Products Div.					2	100,000	100,000
Braeburn Alloy Steel Corp.					2	20,730	20,730
Byers Co., A. M.					2	90,000	90,000
Cabot Shops Inc.					1	14,500	14,500
Cameron Iron Works Inc.					2	58,800	58,800
Carpenter Steel Co.					6	86,600	86,600
Colorado Fuel & Iron Corp.	27	2,594,500					2,594,500
‡Roebling's Sons Corp., J. A.	9	235,000					235,000
Columbia Tool Steel Co.					2	6,600	6,600
Continental Steel Corp.	5	420,000					420,000
Copperweld Steel Co.					7	660,000	660,000
Crucible Steel Co. of America	9	1,044,000			17	379,400	1,423,400
Detroit Steel Corp.	15	1,500,000					1,500,000
Eastern Stainless Steel Corp.					4	50,000	50,000
Edgewater Steel Co.	3	117,600					117,600
Empire Steel Corp.	7	500,000					500,000
Erie Forge & Steel Corp.	5	234,000					234,000
Finkl & Sons Co., A.					2	33,600	33,600
Firth Sterling Inc.					3	20,040	20,040
Ford Motor Co.	10	1,677,150			5	200,250	1,877,400
Granite City Steel Co.	7	1,200,000					1,200,000
Green River Steel Corp.					2	183,190	183,190
Harrisburg Steel Co., Div. of Harsco Corp.	3	100,750					100,750
Heppenstall Co.	2	50,470			1	5,080	55,550
Hooter Steel Corp.					1	12,000	12,000
Inland Steel Co.	40	5,500,000					5,500,000
International Harvester Co.	11	1,200,000					1,200,000
Isaacson Iron Works					2	102,000	102,000
Jessop Steel Co.					4	35,740	35,740
Jones & Laughlin Steel Corp.	37	5,998,000	3	600,000	1	2,000	6,600,000
Joslyn Mfg. & Supply Co.					3	37,500	37,500
Judson Steel Corp.	3	76,500					76,500
Kaiser Steel Corp.	9	1,536,000					1,536,000
Keystone Steel & Wire Co.	4	450,000					450,000

* Capacities of foundries which normally produce steel only for castings are not included. † Figures represent net steel capacity after average deduction of 9.5 pct was made by producers for operating time lost because of rebuilding, relining, repairs, and holiday shutdowns. ‡ Indicates subsidiaries. § Crucible furnace. ** Includes three oxygen converters, annual capacity 540,000 tons. ‖ Used in melting.

Furnaces as of Jan. 1, 1957

Company	No. of Stacks	Total Annual Capacity, Net Tons*
National Steel Corp.:		
†Great Lakes Steel Corp.	4	2,120,000
†Hanna Furnace Corp.	4	850,000
†Weirton Steel Co.	4	2,100,000
New Jersey Zinc Co.	2	**112,000
Pittsburgh Coke & Chemcal Co.	3	836,500
Pittsburgh Steel Co.	[illegible]	980,000
Republic Steel Corp.	22	7,733,000
Sharon Steel Corp.	[illegible]	814,400
Shenango Furnace Co.	2	445,450
Tonawanda Iron Div., American Radiator & Standard Sanitary Corp.	1	165,000
United States Pipe & Foundry Co.	4	491,710
United States Steel Corp.:		
†United States Steel Corp. (Central Operations)	50	††19,410,300
†American Steel & Wire Div.	6	1,693,000
†Columbia-Geneva Steel Div.	5	1,804,200
†National Tube Div.	[illegible]	3,275,000
†Tennessee Coal & Iron Div.	9	§13,209,000
Wheeling Steel Corp.	6	1,860,000
Woodward Iron Co.	4	772,630
Youngstown Sheet & Tube Co.	13	4,140,000
Grand Total	262	§§80,817,950

** Spiegeleisen only. †† Includes 237,600 tons ferroalloys capacity. ‡‡ Includes 39,000 tons ferroalloys capacity. §§ Includes 788,600 tons ferroalloys capacity.

Steel for Castings) As of Jan. 1, 1957*

Company	Open Hearth		Bessemer		Electric and Crucible		Total Annual Capacity, Net Tons†
	No.	Annual Capacity, Net Tons†	No.	Annual Capacity, Net Tons†	No.	Annual Capacity, Net Tons†	
Kilby Steel Co.					1	34,020	34,020
Knoxville Iron Co.					2	38,000	38,000
Laclede Steel Co.	4	500,000					500,000
Latrobe Steel Co.					5	24,000	24,000
Le Tourneau Inc., R. G.					3	83,100	83,100
Lone Star Steel Co.	4	550,000					550,000
Lukens Steel Co.	12	750,000					750,000
McLouth Steel Co.					**9	**1,380,000	1,380,000
Merritt-Chapman & Scott Corp.:							
‡Milton Steel Products Div.					3	80,000	80,000
Mesta Machine Co.	8	121,000			1	20,000	141,000
Midvale-Heppenstall Co.	3	100,800			3	62,550	163,350
Mississippi Steel Corp.					1	45,000	45,000
National Forge & Ordnance Co.					3	25,000	25,000
National Steel Corp.:							
‡Great Lakes Steel Corp.	17	3,200,000	††2				3,200,000
‡Weirton Steel Corp.	14	3,000,000	††2				3,000,000
National Supply Co.					3	50,200	50,200
Newport News Shipbuilding & Dry Dock Co.					3	12,000	12,000
Northeastern Steel Corp.	3	188,280			2	114,920	303,200
Northwest Steel Rolling Mills Inc.					2	48,600	48,600
Northwestern Steel & Wire Co.					5	825,000	825,000
Oregon Steel Mills					3	120,000	120,000
Pacific States Steel Corp.	3	216,000					216,000
Pittsburgh Steel Co.	12	1,320,000					1,320,000
Porter Co. Inc., H. K.:							
‡Connors Steel Div.					4	199,000	199,000
‡Vulcan Crucible Steel Co.					2	9,600	9,600
Republic Steel Corp.	78	8,840,000	2	665,000	26	1,542,000	11,047,000
Roanoke Electric Steel Corp.					1	24,000	24,000
Rotary Electric Steel Co.					6	300,000	300,000
Sharon Steel Co.	17	1,826,000			2	72,000	1,898,000
Simonds Saw & Steel Co.					3	21,600	21,600
Southern Electric Steel Co.					2	66,000	66,000
Southwest Steel Rolling Mills					1	45,000	45,000
Texas Steel Co.					3	70,450	70,450
Timken Roller Bearing Co.					9	700,000	700,000
Union Electric Steel Corp.					2	26,760	26,760
United States Steel Corp.:							
‡United States Steel Corp. (Central Operations)	177	24,949,000	118	1,284,000	9	387,000	26,620,000
‡American Steel & Wire Div.	26	2,275,000					2,275,000
‡Columbia-Geneva Steel Div.	19	2,679,000					2,679,000
‡National Tube Div.	15	3,021,000	6	990,000			4,011,000
‡Tennessee Coal & Iron Div.	23	3,997,000	††3				3,997,000
Universal-Cyclops Steel Corp.					5	70,160	70,160
Vanadium-Alloys Steel Co.					4	12,000	12,000
‡Colonial Steel Co.					2	30,000	30,000
Washburn Wire Co.	4	93,000					93,000
Wheeling Steel Corp.	11	1,630,000	2	570,000			2,200,000
Wickwire Brothers Inc.					2	30,300	30,300
Youngstown Sheet & Tube Co.	41	6,180,000	2	60,000			6,240,000
Grand Total	921	116,912,410	§§33	4,505,000	** §271	12,041,740	133,459,150

charge for open hearth furnaces. †† Includes three converters used only in melting charge for open hearth furnaces. §§ Includes ten converters used only in melting charge for open hearth furnaces. * Includes one crucible furnace, annual capacity, 40 tons.

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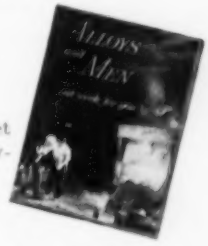

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C. C. Wissman
Pacific Southern Foundries

Finance Committee

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J. P. Bankson
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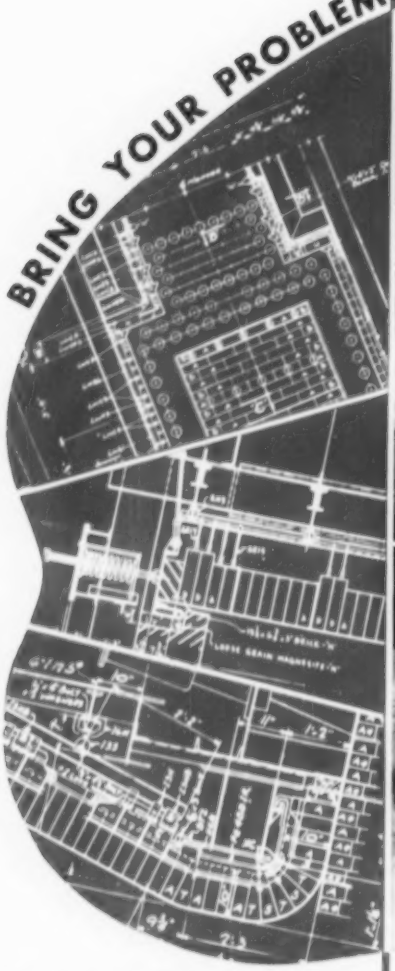
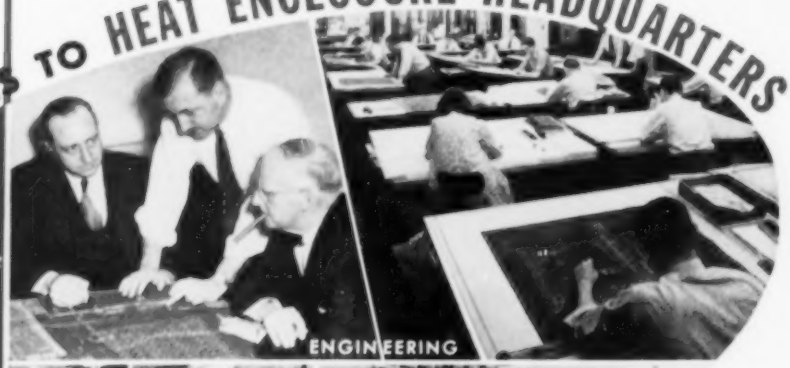
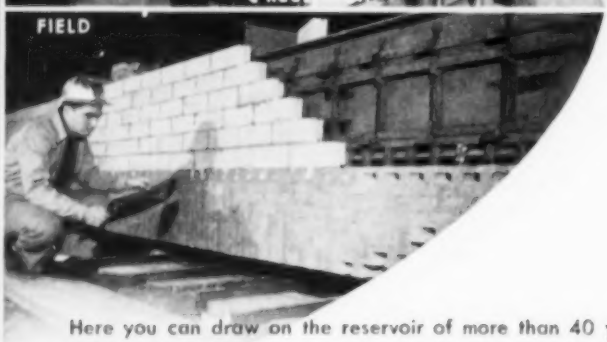
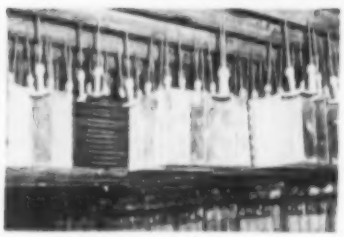
R. W. SHEARMAN
SECRETARY-TREASURER
AIME

BRING YOUR PROBLEMS TO HEAT ENCLOSURE HEADQUARTERS









212 open hearths now have Detrick construction, contributing to better performance in each case. A number of units have recently installed Detrick all basic flat suspended roofs.

Here you can draw on the reservoir of more than 40 years of experience in designing and engineering in this specialized field. Here you can put your trust in an organization that has had a life-long policy of making sure that the installation is a success. Here you will find heat enclosure designs engineered to make use of the latest developments of materials and methods.

TEMPERATURE PROBLEMS. Detrick constructions provide for a wide range of temperature requirements from open hearth furnaces through oil refinery heaters to hot gas flues.

HEAT LOSS PROBLEMS. Block and castable insulations as an integral part of Detrick designs cut heat loss to a safe minimum.

CONTOUR PROBLEMS. Detrick supported roofs and walls provide the structural flexibility to meet any contour or span.

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111 W. Washington Street • Chicago 2, Illinois

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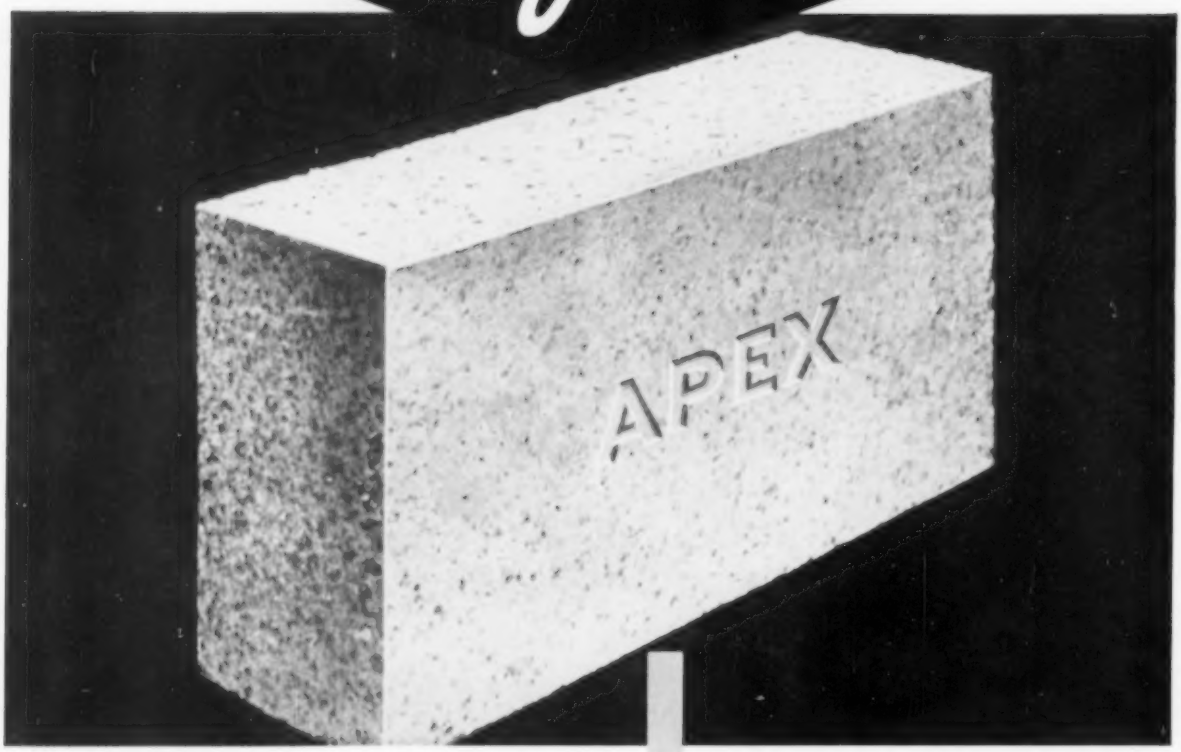

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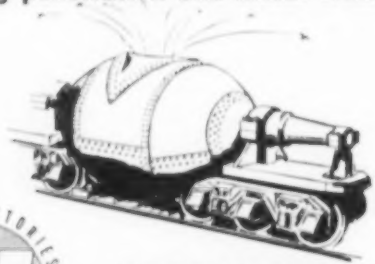
Last word in high bulk density, low porosity, high heat transfer, maximum resistance to slag penetration and metal wash.



Designed specifically for use in lining closed and semi-closed hot metal torpedo type ladles, hot metal mixers and for checkering open hearths and hot blast stoves—Walsh Apex offers greater value per dollar invested. Isn't this the kind of economical service you want from the refractories you use? Write for details.

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National Open Hearth Steel Committee

Local Section Activities

Pittsburgh Section

During the past year the **Pittsburgh Section** held an Iron & Steel Div. dinner meeting in conjunction with the AIME Pittsburgh Section on May 17, 1956. Guest speaker for the occasion was Dr. F. D. Richardson of England, who discussed *The Chemistry of Sulfur in Iron and Steelmaking.*

The spring golf party at the Pittsburgh Field Club on June 13, 1956, saw a turnout of 220 members and guests, while the evening dinner was attended by 350. R. M. Barnhart served as toastmaster, and J. T. Meell as chairman of the arrangements committee.

The 11th annual off-the-record meeting took place on Nov. 2, 1956, at the Penn-Sheraton Hotel, with a total registration of 844 representing the joint effort of all local AIME divisions including the Coal Div., IMD, Petroleum Div., and the Minerals and Metals Economic Committee, in addition to the NOHC. W. D. Doty served as general program chairman for AIME, assisted by W. O. Philbrook for NOHC, and D. H. Davis for the Coal Division.

Through the courtesy of the suppliers, a cocktail party was held prior to the Fellowship Dinner, the latter attended by 396. A total of 98 engineering students were guests of individual members and the Pittsburgh Sections, AIME-NOHC, at the technical sessions and the Fellowship Dinner. Toastmaster N. K. Flint had the pleasure of introducing AIME President Carl E. Reistle, Jr. and guest speaker Perry E. Gresham, president of Bethany College. The F. L. Toy Award was presented to John F. Elliott, Kurt R. Mattson, and John Tatu, Jr. for their paper *Influence of Ingot Dimensions on Segregation in Large Rim Steel Ingots.*

The Section's plans for the future include a spring golf party on Monday, June 10, 1957, at the South Hills Country Club. The Penn-Sheraton Hotel, Pittsburgh, will be the site of the annual off-the-record meeting, Nov. 1, 1957, at which function G. L. Owens will serve as program chairman.

Present officers of the Pittsburgh-NOHC Section are: D. L. McBride, U. S. Steel Corp., chairman; R. M. Barnhart, Alco Products Corp., vice chairman; E. B. Snyder, Wheeling Steel Corp., secretary; and J. H. Smith, Steel Publications Inc., treasurer.

D. L. McBRIDE

U. S. Steel Corp.,
Pittsburgh
Chairman,
Pittsburgh Section

Chicago Section

The **Chicago Section** had a busy successful year. At the spring dinner meeting held at Phil Smidt's Restaurant on May 7, 1956, H. V. Flagg of Armco Steel Corp. presented an interesting paper on *Combustion of Liquid Fuel in Open Hearth Furnaces.* Audience participation was unusually good at this meeting, presided over by technical chairman Courtney Sarrels of U. S. Steel Corp.'s Gary Works.

The annual golf party was held at Medlothian Country Club on Sept. 11, 1956, at which time 200 took part in the sport and 420 were present for the dinner afterward.

Highlight of the fall dinner meeting on Oct. 1, 1956, was a panel discussion on the use of pneumatic and mechanical equipment for open hearth furnace maintenance, as well as materials used with this equipment. A. M. Kroner presided.

T. D. HESS

Youngstown Sheet &
Tube Co.,
East Chicago, Ind.
Chairman,
Chicago Section

The Del Prado Hotel was the scene of the all-day off-the-record meeting on Mar. 13, 1956. Subjects discussed included the use of basic brick for roof and end construction, hot tapping practice, light up procedures following furnace rebuilds, and bath temperature control. The Section contest was won by K. V. Smith, Gary Works, U. S. Steel Corp., while R. J. Tatousek and A. F. Peters, of Inland Steel Co., were awarded second place honors.

(Continued on page 560)

(Continued from page 559)

Officers for 1957 are: H. Erler, Gary Works, U. S. Steel, chairman; M. Nickel, Wisconsin Steel Works, International Harvester, vice chairman; and A. M. Kroner, Inland Steel, secretary-treasurer.

Detroit Section

The Detroit Section got under way last year with their first meeting held February 29. At this organizational conclave, 129 were present. All of the principal steel producing companies in the area—Ford Motor Co., Great Lakes Steel Corp., Rotary Electric Steel Co., and McLouth Steel Corp., were well represented. AIME Secretary E. Kirkendall, former NOHC Secretary, discussed the aims and achievements of NOHC.

The second dinner-meeting was held at the Engineering Society of Detroit. Principal speaker of the evening was James J. Bowden, of the Bowflux Co. His topic, *Melting Practice and its Effect on Finished Steel*, was very well received by the audience of 130.

W. H. Mayo, manager of process control metallurgy, U. S. Steel Corp., Pittsburgh, opened the year 1957 for the Section, by presenting a paper on *Training Personnel in the Control of Sulfur in the Open Hearth*. At this dinner-meeting, more than 140 were present.

The NOHC Detroit Section and the AIME Detroit Chapter joined forces to stage a two-day Regional Meeting, March 18 and 19, 1957, on *Deep Drawing Steels*. The program covered process metallurgy and physical metallurgy of deep drawing steels from raw material to fabrication.

P. E. LINDBERG

McLouth Steel Corp.
Trenton, Mich.
Chairman,
Detroit Section

Southwestern Section

The usual spring meeting of the **Southwestern Section** was held in St. Louis on Feb. 9, 1956, at Hotel Lennox. At that time, the Section authorized an annual award of $100 for the best paper submitted which could be used in the October Technical Session.

The Annual Globe Trotters' Meeting was in Pueblo and Colorado Springs Sept. 27-28, 1956. Host for this meeting was the Colorado Fuel & Iron Corp. On Thurs. September 27, members and guests visited the plant of CF&I, followed by lunch at the Pueblo Golf & Country Club, as guests of the company. Afterward they returned to the Broadmoor Hotel

J. M. BRASHEAR

Lone Star Steel Co.,
Lone Star, Texas
Chairman,
Southwestern Section

for the technical sessions. On Thurs. evening a dinner party was held at the Garden of the Gods Club, sponsored by E. J. Lavino & Co. The technical session the following day broke all Section meeting attendance records. A highlight of the day's activities was the Suppliers Cocktail Party, culminated by the Fellowship Dinner which was attended by 175 members and guests.

The ladies had a fine time too. While the technical sessions were in progress the wives were conducted on tours of Colorado Springs, as guests of CF&I, and in the evening they enjoyed a dinner at the Garden of the Gods Club; E. J. Lavino & Co. were hosts.

Eastern Section

During the last year the **Eastern Section** held several highly successful meetings. On May 11, 1956, over 200 members participated in a tour through Alan Wood Steel Co. at Conshohocken, Pa. A total of 60 companies (suppliers and steel producers) were represented. Mills visited by the group included the Open Hearth, Blooming Mill, Plate Mill, Hot Strip Mill, and the Cold Strip Mill.

After their visit to the Steel Works, guests were taken by way of the Blast Furnace and Coke &

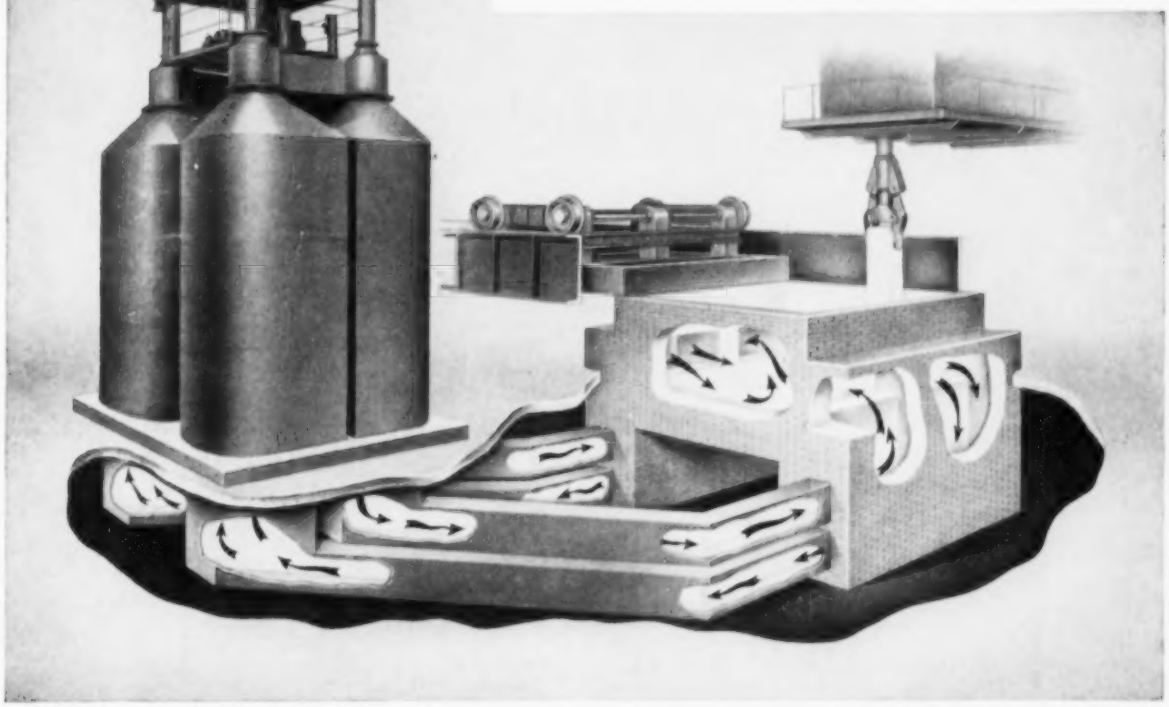
(Continued on page 562)

C. D. MOORE

G. & W. H. Corson
Co. Inc.
Plymouth Meeting,
Pa.
Chairman,
Eastern Section

HEAT MORE STEEL with MORGAN-ISLEY

The Morgan-Isley system offers you a better means of heating ingots with straight blast furnace gas, coke oven gas, natural gas or oil.



The schematic shows the flow of combustion air and flue gases through the regenerators and soaking pit. The Morgan-Isley system employs vertical regenerators. It eliminates regenerator capacity under the crane runway thus freeing this valuable area for heating steel.

CCC-B

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H.H. Wood, Representative, Koppers Building, Pittsburgh, Pennsylvania

(Continued from page 560)

Chemicals Depts., to a luncheon at the Valley Forge Hotel in Norristown. Favors commemorating the occasion were distributed.

The tenth annual technical conference held at the Warwick Hotel, Philadelphia, on Oct. 12, 1956, was attended by approximately 300 guests. The program opened with the presentation of the award winning paper, *Results of Improved Combustion Conditions in a Small Cold Metal Shop* by G. M. Hagenberger, Standard Steel Works Div., Baldwin-Lima-Hamilton Corp. The remainder of the morning session was devoted to a panel discussion covering general open hearth problems. In the afternoon, papers were presented on a fuel control system, safety, refractories, quality, and the use of a spectrometer.

The evening activities were in a lighter vein, with entertainment furnished by the Suppliers Committee. After an excellent steak dinner, the guests were amused by Dan Loughrey, Jones & Laughlin Steel Corp., who offered some diverting stories. Later he presented an interesting review of the growth of the U. S. iron and steel industry. Mr. Loughrey emphasized the continuing and growing need for technically trained men in the industry.

The Section has big plans for 1957, including a visit to the Claymont Plant of CF&I, the first annual outing and golf party at the Coatesville, Pa., Country Club and the annual technical meeting scheduled for Oct. 11, 1957.

Buffalo Section

Activities of the **Buffalo Section** in 1956 included the third annual golf party on May 24, 1956 at the Wanakah Country Club, with 138 registrants. The golf tournament was followed by a dinner at which time prizes were distributed through the courtesy of the Open Hearth Suppliers Committee.

The Seventh Annual Fall Meeting was held on Nov. 13, 1956, in the Hotel Statler, with 209 members and guests in attendance, many of whom took a guided tour of Chevrolet Forge Plant.

At the technical session in the afternoon, the speakers were J. W. Tysse, Republic Steel Corp.; Ralph D. Hindson, and J. D. Sloane, both of Steel Co. of Canada Ltd.

The principal speaker at the Annual Banquet was Clarence F. Luck, public relations supervisor, N. Y. Telephone Co., whose topic was *The Transistor—The Mighty Mite.*

Joseph L. Walton, who was elected Section chairman for 1957 has resigned since he was transferred from the Lackawanna plant of Bethlehem Steel Co., where he was open hearth superintendent, to the Johnston plant where he will be assistant general manager. Until new elections are held at the next annual meeting, November 1957, in Hamilton, Ontario, vice chairman J. R. Atkinson of Dominion Foundries & Steel Co., will serve as chairman of the Section. Harry A. Morlock is secretary-treasurer.

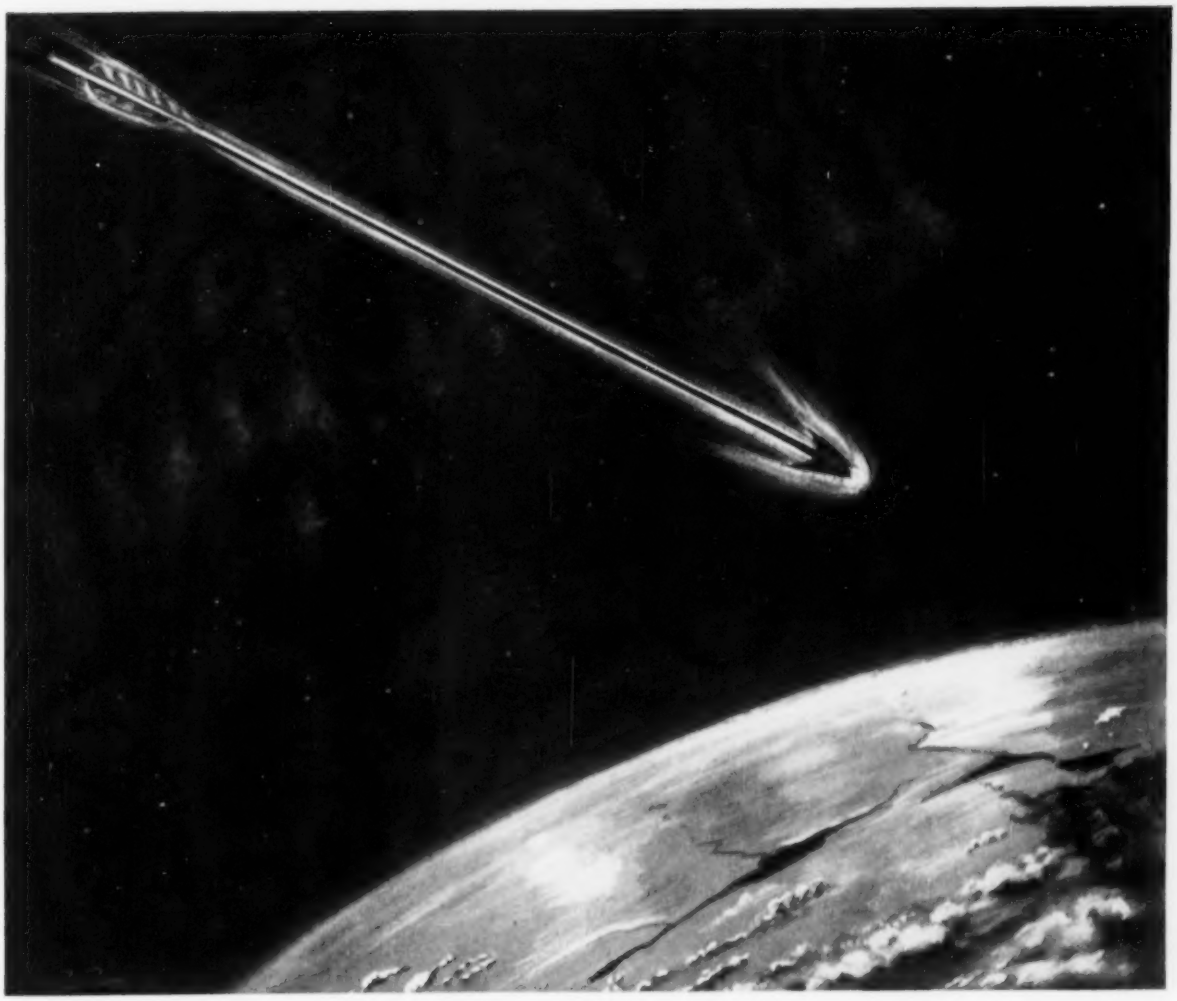
AISI Capacity Tables *(Continued from page 551)*

Annual Coke Capacity as of Jan. 1, 1957

Company	Beehive		Other		Total Annual Capacity, Net Tons*
	No. of Ovens	Annual Capacity, Net Tons*	No. of Ovens	Annual Capacity, Net Tons*	
Alan Wood Steel Co.			151	600,000	600,000
Armco Steel Corp.			186	1,045,000	1,045,000
†Sheffield Div.			62	360,000	360,000
Bethlehem Steel Co.			2,208	11,450,000	11,450,000
Colorado Fuel & Iron Corp.			266	1,220,000	1,220,000
Crucible Steel Co. of America			213	831,600	831,600
Detroit Steel Corp.			108	550,000	550,000
Eastern Gas & Fuel Assoc.			108	664,000	664,000
Ford Motor Co.			220	1,320,790	1,320,790
Granite City Steel Co.			76	450,000	450,000
Inland Steel Co.			505	2,598,190	2,598,190
Interlake Iron Corp.			400	1,637,000	1,637,000
International Harvester Co.			155	750,000	750,000
Jones & Laughlin Steel Corp.			831	3,888,000	3,888,000
Kaiser Steel Corp.	297	100,000	225	1,006,000	1,106,000
Lone Star Steel Co.			78	438,000	438,000
Merritt-Chapman & Scott Corp.:					
†Tennessee Products & Chemical Corp.			44	251,500	251,500
National Steel Corp.:					
†Great Lakes Steel Corp.			294	2,000,000	2,000,000
†Hanna Furnace Corp.			126	1585,000	1585,000
†Weirton Steel Co.			294	1,900,000	1,900,000
Pittsburgh Coke & Chemical Co.			140	1,000,000	1,000,000
Pittsburgh Steel Co.	320	228,000	93	644,000	872,000
Republic Steel Corp.	296	215,000	1,128	16,064,000	16,279,000
Sharon Steel Corp.			60	225,000	225,000
†Carpentertown Coal & Coke Co.	277	160,000			160,000
United States Pipe & Foundry Co.			180	900,000	900,000
United States Steel Corp.:					
†U. S. Steel Corp. (Central Operations)	1,716	1,042,600	3,043	14,650,800	15,693,400
†American Steel & Wire Div.			295	1,418,100	1,418,100
†Columbia-Geneva Steel Div.			308	1,345,700	1,345,700
†National Tube Div.			354	1,602,200	1,602,200
†Tennessee Coal & Iron Div.			558	3,032,500	3,032,500
Wheeling Steel Corp.			314	1,720,000	1,720,000
Woodward Iron Co.			256	938,000	938,000
Youngstown Sheet & Tube Co.			780	4,140,000	4,140,000
Grand Total	2,906	1,745,600	14,059	71,225,380	72,970,980

* Figures represent net coke oven capacity after average deduction of 4.8 pct was made for rebuilding, relining, repairs, or age of ovens by companies with two thirds of the total capacity. † Indicates subsidiary. ‡ Indicates 50 pct of coke capacity of the Donner-Hanna Coke Corp., Buffalo.

Acknowledgment is given to the American Iron & Steel Institute for permission to publish these official capacity figures. All data were compiled by AISI, and are correct as of Jan. 1, 1957.



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Away up where it's cold, black and lonely at 500,000 ft., the thermal attack on a missile or "airplane" isn't very meaningful. The air molecules at that height are barely nodding neighbors, rather than crammed together in a fluid mass. But, escape and re-entry into the earth's dense envelope of atmosphere generate thermal attacks of frightening ferocity. Nose and leading-edge temperatures may rise to 3000°F.

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Production quantities of very high strength heat-treated sheet, to close gage and flatness tolerances, are being engineered into advanced aircraft and missiles. For non-military applications, all types of mill products are obtainable at constantly lower price levels.

T.M.C.A. is again adding to its production facilities to properly service an ever-expanding market. T.M.C.A. engineering service and technical literature are readily available to all those industries challenged by weight, strength and corrosion problems.

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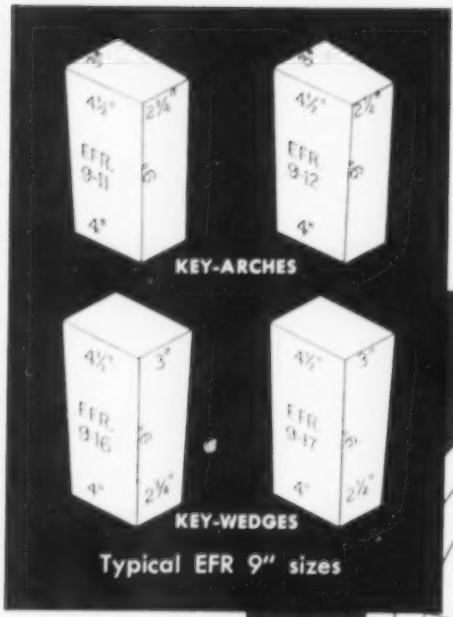
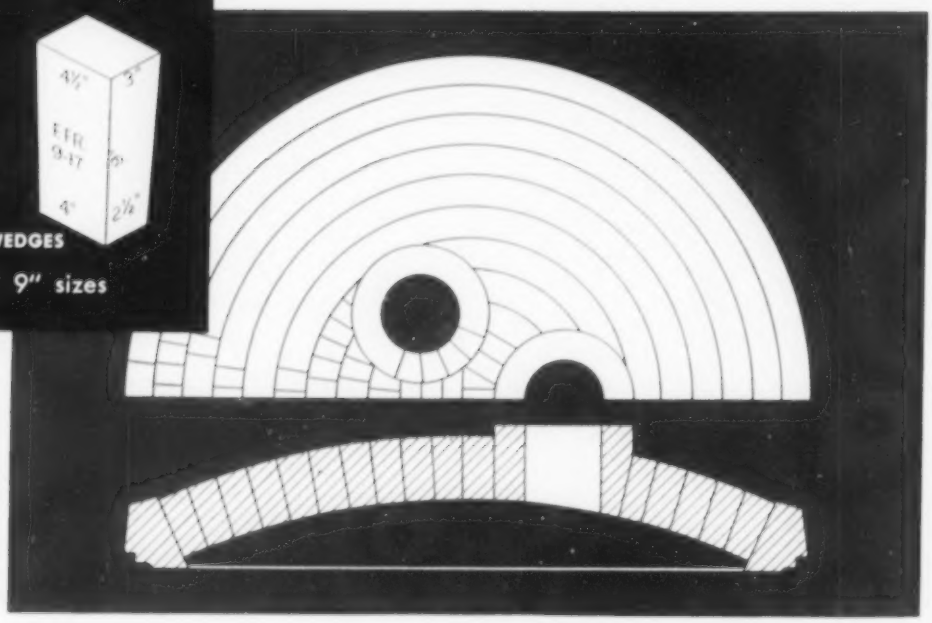
provides important benefits





Harbison-Walker EFR (electric furnace roof) brick are modified 9" key-arches and key-wedges, designed for use in combination with a large proportion of standard 9 x 4½ x 3" sizes in the construction of roofs of any diameter and rise.

The use of these EFR shapes insures a close fit of the brick and roof construction of best workmanship.

The number of different sizes required for building a roof with the aid of the EFR brick is greatly reduced for some designs.

Bricklaying is simplified and much time is saved when EFR brick are used.

EFR brick are power pressed by which method of forming all of the most desirable physical properties are secured.

Roofs built of smaller brick units in preference to large special shapes generally prove to be more serviceable. The smaller sizes are more resistant to thermal shock.

The EFR shapes cost less than large special shapes and since they are used with standard 9" sizes in predominance, the overall cost is considerably reduced.

H-W High Alumina Castable and Korundal Ramming Mix sometimes are used to advantage as a monolith to facilitate easy fitting in the center section.

The EFR brick, together with the standard 9" sizes needed for complete roofs, are furnished in the types and classes of refractories best suited for the various operating conditions. For example, they are made in the following brands: STAR and VEGA silica brick; H-W MULLITE; KORUNDAL; and various Harbison-Walker superduty brands, such as ALAMO and H-W SUPER SAVAGE.

The combination of quality, H-W Technical Service and balanced selection based on availability of all types and classes of refractories from one source, provides maximum economy.

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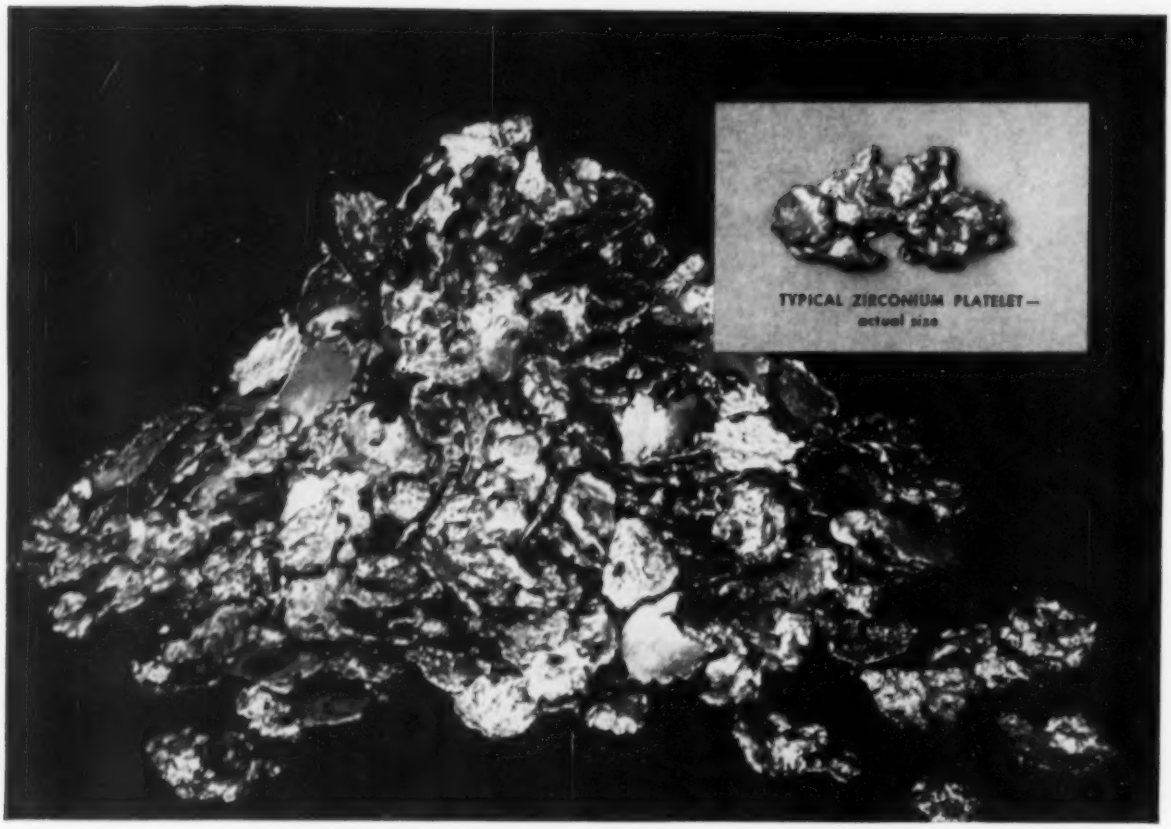

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Lower Price

Reactor grade will be priced at $4.75 to $6.50 a pound, depending on quantity. Commercial grade will sell at about $1.50 less. These low prices will be possible because U.S.I., as a prime producer of sodium metal, uses a semi-continuous sodium reduction process—the most economical production technique ever developed for reducing metallic chlorides.

Higher Quality

U.S.I. zirconium will offer users top quality, too. In the first place, U.S.I. starts with sodium, a higher purity raw material than the reducing agents commonly used in other processes. Then, the technique itself yields a product of higher purity and uniformity. Finally, in making its zirconium platelets U.S.I. virtually eliminates chloride, magnesium, sodium and hydrogen impurities.

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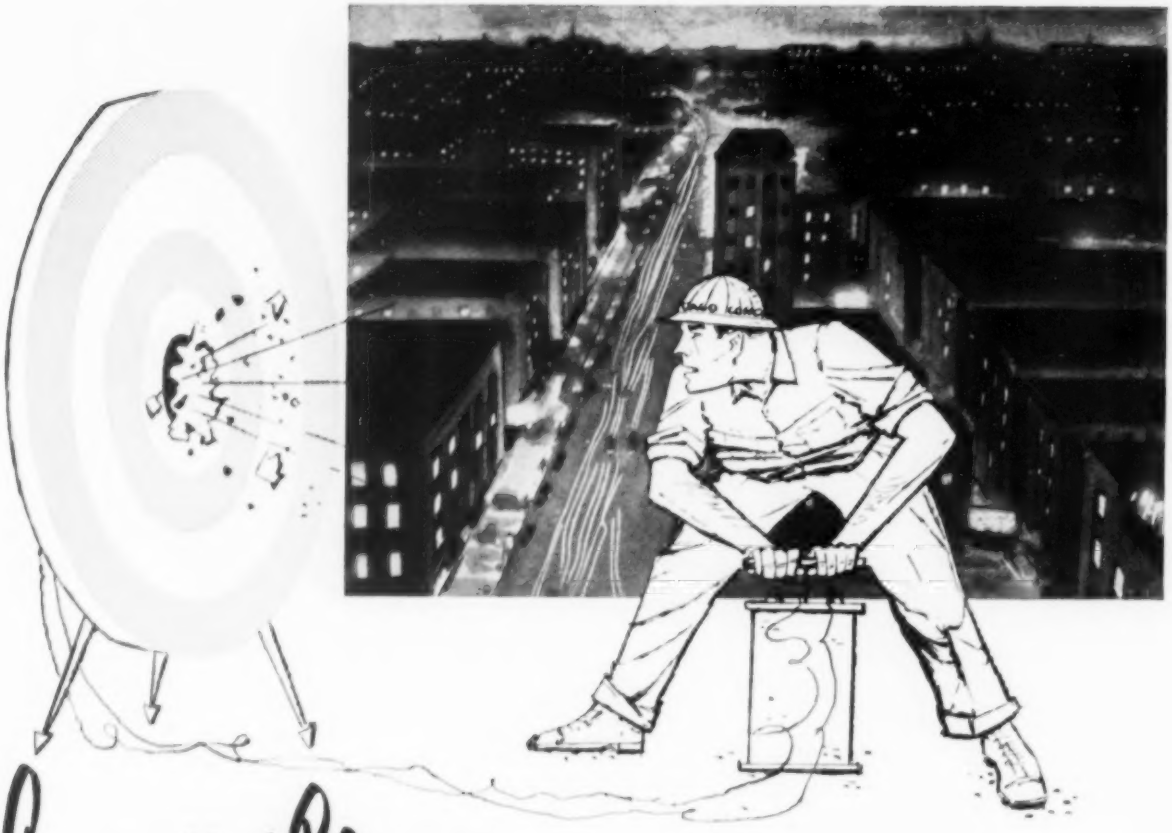

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PROGRAMS

Blast Furnace, Coke Oven, and Raw Materials Committee and National Open Hearth Steel Committee

The Penn-Sheraton Hotel, Pittsburgh, will be the scene of the 40th conference, held April 8 through 10, 1957. Registration will be in the Fort Duquesne Room, 17th Floor, 3 to 9 pm, Sunday, April 7; 8 am to 5 pm, Monday, April 8; 8 am to 5 pm, Tuesday, April 9; and 8 am to 4 pm, Wednesday, April 10. Special train for the plant trip on Wednesday, April 10, will leave the Pennsylvania Railroad Station, Pittsburgh, at 9:00 am, arriving in Weirton at 10:25 am, and will leave Weirton at 4:00 pm, arriving in Pittsburgh at 5:25 pm. Checkout time at the Penn-Sheraton Hotel has been extended to 6:30 pm. On Monday and Tuesday, April 8 and 9, authors and session chairmen for each day's program will meet for breakfast at 8 am in Parlors B and C.

Blast Furnace, Coke Oven, and Raw Materials Conference

Monday, April 8

Blast Furnace Practice Session

9:30 am to 12:15 pm—Urban Room

Chairmen: *J. S. McMahan*, Superintendent, Blast Furnaces, The Steel Co. of Canada Ltd., Hamilton, Ont., Canada, *and F. C. Anderko*, Assistant Superintendent, Blast Furnace Div., Sintering Plant, Ore Handling, Screening Station, Bethlehem Works, Bethlehem Steel Co., Bethlehem.

Welcoming Remarks: *C. T. Marshall*, General Manager, Coke and Iron Div., Pittsburgh Coke and Chemical Co., Pittsburgh, and General Chairman, AIME Blast Furnace, Coke Oven, and Raw Materials Committee

Blast Furnace Top Construction: *H. M. Kraner*, Ceramic Engineer, Bethlehem Steel Co., Bethlehem

Experience With Stack Cooling Plates: *J. W. Duncan*, Superintendent, Blast Furnaces, *and R. E. Turman*, Technological Coordinator-Blast Furnaces, Gary Steel Works, U. S. Steel Corp., Gary

A Note on Bosh Construction and Bosh Tuyeres: Preprinted paper by *G. D. Elliot*, Works Manager—Iron, Appleby-Frodingham Works, United Steel Companies Ltd., Scunthorpe, Lincolnshire, England

Tuyere Development at Bethlehem: *L. W. Butz*, Assistant to Superintendent, Blast Furnace Div., Bethlehem Steel Co., Bethlehem

The Orifice Plate Gas Washer: *J. R. Lowe*, Superintendent, Blast Furnaces, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh

Blast Furnace, Coke Oven, and Raw Materials Executive Board Luncheon

12:30 pm—Parlors B and C

Annual Luncheon and Business Meeting, Blast Furnace, Coke Oven, and Raw Materials Committee

Tuesday, April 9

12:30 pm—Monongahela Room

C. T. Marshall, Chairman

Everyone attending the Blast Furnace, Coke Oven, and Raw Materials Conference is invited to attend this luncheon and annual business meeting.

(Tickets, $3.50, tips and tax included.)

Blast Furnace Theory Session

2:00 to 5:00 pm—Urban Room

Chairmen: *J. B. Wagstaff*, Physicist, Research Laboratory, United States Steel Corp., Monroeville, Pa., *and W. H. Holman*, Assistant Manager, Steubenville Works, Wheeling Steel Corp., Steubenville, Ohio

H-Iron Process: Preprinted paper by *A. M. Squires*, Director of Process Development, *and C. A. Johnson*, Director of Research, Hydrocarbon Research Inc., New York

Slag-Metal Reaction of Chromium in Carbon-Saturated Melt: *C. W. McCoy*, Products and Processes Development Dept., Electro Metallurgical Co., Div. of Union Carbide and Carbon Corp., Niagara Falls, N. Y., *and W. O. Philbrook*, Professor, Metallurgical Engineering, Carnegie Institute of Technology, Pittsburgh

Pig Iron Production in the Electric Furnace: *C. E. Lesher*, Consulting Engineer, Oliver Building, Pittsburgh

Coal and Coke Session

2:00 to 5:00 pm—Allegheny Room

Chairmen: *A. D. Shattuck*, Superintendent, Coke Plant, Great Lakes Steel Corp., Detroit, *and C. V. Thompson*, Superintendent, Coke Plant, Crucible Steel Co. of America, Midland, Pa.

Symposium on Maintaining and Operating a Coke Plant During Curtailment of Operations: *J. H. Kunkle*, Superintendent, Coke Plant, Republic Steel Corp., Warren, Ohio
Peter Palumbo, Coke Plant Staff Engineer—Operation Practice, United States Steel Corp., Clairton, Pa.
C. L. Corban, Manager, Coke Production, Inland Steel Co., East Chicago

Discussion: *J. J. Carett*, Superintendent, By-Product Coke Plant, Jones & Laughlin Steel Corp., Aliquippa, Pa.

Tuesday, April 9

Ore Agglomeration Session

9:30 am to 12:15 pm—Urban Room

Chairmen: *James Chisholm*, Assistant Superintendent, Blast Furnaces, Fairless Works, United States Steel Corp., Morrisville, Pa., *and Stanley Sundeen*, Manager, Ore Development, Cleveland-Cliffs Iron Co., Ishpeming, Mich.

Taconite Pellets—Problems of Car Loading, Stockpiling, and Loading Lake Vessels at Erie Mining Company: *L. O. Millard*, Assistant General Sales Manager, Link-Belt Co., Chicago

Updraft Method of Pelletizing Specular Hematite Flotation Concentrates: *D. C. Violetta*, Pyrometallurgist, Research Laboratory, Cleveland-Cliffs Iron Co., Ishpeming, Mich.

How Can Theory Help Us to Make More Sinter?: Preprinted paper by *E. W. Voice and R. Wild*, The British Iron and Steel Research Assn., London, England

Distribution of Sinter Mix by the Swinging Spout Method: Preprinted paper by *W. J. Eisman*, Development Metallurgist, Coke Plant and Blast Furnaces, *D. R. Dalton*, Product Metallurgist, *and J. T. O'Connor*, Development Technologist, Gary Steel Works, United States Steel Corp., Gary

Byproduct Session

9:30 am to 12:15 pm—Monongahela Room

Chairmen: *J. D. Price*, Superintendent, By-Product Coke Plant, Colorado Fuel & Iron Corp., Pueblo, Colo., *and R. O. Bowman*, Superintendent, Coke Plant, Weirton Steel Co., Weirton, W. Va.

Byproduct Coke Industrial Waste Guide: Preprinted paper by *H. H. Black*, Chief, Industrial Wastes Studies, *G. N. McDermott*, Sanitary Engineer, Industrial Wastes Studies, *C. Henderson*, Aquatic Biologist in Charge, Bioassay Application Studies, *W. A. Moore*, Chemist in Charge, Analytical Methods Unit, *and H. R. Pahren*, Senior Assistant Sanitary Engineer, Industrial Wastes Studies, Robert A. Taft Sanitary Engineering Center, United States Public Health Service, Cincinnati

Biological Treatment of Byproduct Coke Plant Phenolic Wastes: Preprinted paper by *N. W. Trepanier*, Supervisor, Project Engineering Section, Plant and Production Engineering Dept., Steel Div., Ford Motor Co., Dearborn

What Will Sell and Why: *W. R. Morgan*, Hydrocarbon Products Co. Inc., New York

Blast Furnace and Coke Oven Joint Session

2:00 to 5:00 pm—Urban Room

Chairmen: *N. W. Lindbloom*, Superintendent, Blast Furnaces, Edgar Thomson Works, United States Steel Corp., Braddock, Pa., *and A. D. Shattuck*, Superintendent, Coke Plant, Great Lakes Steel Corp., Detroit

Knowing's Not Enough (Talk and Motion Picture on Safety): *Dan Farrell*, Director of Safety, United States Steel Corp., Pittsburgh

Ironmaking in the USSR—Impressions Gained From Visits and the Literature: Preprinted paper by *E. W. Voice and S. Klemantaski*, The British Iron and Steel Research Assn., London, England

Better Utilization of Coking Coals: *A. H. Brisse*, Chief Research Engineer—Coal and Coke, Applied Research and Development, United States Steel Corp., Pittsburgh

High-Temperature Testing of Blast Furnace Coke: Preprinted paper by *M. O. Holowaty*, Chief of Raw Materials Research, Research and Development Dept., *and C. M. Squarcy*, Manager, Iron Production, Blast Furnace Dept., Indiana Harbor Works, Inland Steel Co., East Chicago

Annual Fellowship Dinner

Tuesday, April 9

6:30 pm—Urban Room

Reception and Cocktail Party for dinner guests.

7:00 pm—Ball Room

Annual Fellowship Dinner

Toastmaster: *D. R. Loughrey*, Jones & Laughlin Steel Corp., Pittsburgh

Speaker: *Major General John B. Medaris*, Chief of Army Ballistics, Missiles Agency, Redstone Arsenal, Alabama

National Open Hearth Steel Conference

Monday, April 8

General Session

10:00 to 10:30 am—Ball Room

Welcoming Remarks: *D. R. Mathews*, General Manager, Primary Production, Alan Wood Steel Co., and General Chairman, National Open Hearth Steel Committee, AIME

Announcements and Reports

McKune Award Paper

Basic Operations Session

10:30 am to 12:15 pm—Ball Room

Chairmen: *J. F. Pollack*, Superintendent, Open Hearth Dept., Jones & Laughlin Steel Corp., Pittsburgh, *and J. L. Walton*, Assistant General Manager, Bethlehem Steel Co., Johnstown, Pa.

Methods Used During Forced Interruptions in Open Hearth Operations (A Symposium on Results of Industry-Wide Questionnaire): *George Ferris*, Superintendent, Open Hearth Steel Div., Ford Motor Co., Dearborn

Results Obtained From High Firing Rates: *Keith Moore*, Superintendent, Open Hearth Dept., The Steel Co. of Canada Ltd., Hamilton, Ont., Canada

Factors Affecting Heat Time: *T. A. Cleary, Jr.*, melter foreman, Youngstown Sheet & Tube Co., Youngstown

Acid Operations Session

10:30 am to 12:15 pm—Monongahela Room

Chairmen: *F. H. Allison, Jr.*, Vice President, Research Associate, Rolls Div., Blaw-Knox Co., Pittsburgh, *and R. M. Barnhart*, Melting Superintendent, Alco Products Co. Inc., Latrobe, Pa.

Effects of Improved Combustion Conditions in a Small Cold Metal Shop: *G. M. Hagenberger*, Open Hearth Dept., Standard Steel Works Div., Baldwin-Lima-Hamilton Corp., Burnham, Pa.

European Methods of Acid Steelmaking: *P. Herasymenko*, Senior Engineering Scientist, New York University, New York

Physical Chemistry of Steelmaking Luncheon

12:30 pm—Parlors E and F

Operating Metallurgy Session

2:00 to 5:00 pm—Monongahela Room

Chairmen: *D. E. Babcock*, Metallurgical Engineer, Republic Steel Corp., Youngstown, *and J. E. Tredennick*, Div. Metallurgist, Iron and Steel, Kaiser Steel Corp., Fontana, Calif.

Review of paper—Continuous Casting of Three Types of Low-Corbon Steel (presented at AIME Annual Meeting, New Orleans, 1957): *L. E. Kraay*, Open Hearth Assistant Superintendent, Inland Steel Co., East Chicago

Prepared Discussion: *Rufus Easton*, Manager, Continuous Casting Section, Freyn Dept., Koppers Co., Pittsburgh
R. Clark, Atlas Steels Ltd., Welland, Ont., Canada

Analysis of Molten-Steel Flow Rates Through Refractory Nozzles: *C. H. Martin*, Mold Yard Foreman, No. 2 Open Hearth Dept., *and H. L. Taylor*, Supervisor, Field Development Section, Research and Development Dept., Inland Steel Co., East Chicago

Discussions By: *C. R. Taylor*, Supervising Metallurgist, Research Laboratories, Armco Steel Corp., Middletown, Ohio, *and B. M. Larsen*, Research Supervisor, United States Steel Corp., Monroeville, Pa.

High-Speed Movies Showing Flow Characteristics of Liquid Through Nozzles: *J. B. Wagstaff*, Physicist, Research Laboratory, United States Steel Corp., Monroeville, Pa.

Refractories and Masonry Session (I)

2:00 to 5:00 pm—Ball Room

Chairmen: *H. C. Parson*, Supervisor, Masonry and Labor, Lukens Steel Co., Coatesville, Pa., *and George Anthony*, Ceramic Engineer, Youngstown Sheet and Tube Co., Youngstown

New Approach to Open Hearth Maintenance: *E. W. Hunziker*, Div. Superintendent, Open Hearth and Foundry, *and M. E. Strate*, Assistant Div. Superintendent of Maintenance and Utilities, Columbia-Geneva Steel Div., United States Steel Corp., Salt Lake City

Pre-Fabricating New Fronts for Open Hearth Furnaces Saves Time and Money: *A. W. Schoenebeck*, Superintendent, Maintenance and Construction, Granite City Steel Co., Granite City, Ill.

Open Hearth Roof Patching: *C. L. Meloy*, Engineer, Research Dept., Bethlehem Steel Co., Bethlehem

Prepared Discussion By: *R. F. Moore*, Ceramic Engineer, Pittsburgh Works, Jones & Laughlin Steel Corp., Pittsburgh

Effect of Banding and Oil Impregnation of Nozzles on Pouring Performance: *A. Sonz*, Ceramic Engineer-Development, *and R. N. Ames*, General Supervisor, Ceramic Development, South Works, United States Steel Corp., Chicago

Prepared Discussion By: *J. J. Hazel*, Chief Ceramic Engineer, Republic Steel Corp., Cleveland

An Evaluation of Cast Refractory Hot Top Linings: *R. J. Tatousek*, Practice Foreman No. 1 Open Hearth, *and A. T. Peters*, Metallurgist, Quality Control Dept., Inland Steel Co., East Chicago

Prepared Discussion By: *H. W. Clark*, Open Hearth Metallurgist, Steel Div., Ford Motor Co., Dearborn

National Open Hearth Steel Executive Board Dinner

6:00 pm—Park Room, Lobby Floor

Tuesday, April 9

Refractories and Masonry Session (II)

9:30 am to 12:15 pm—Ball Room

Chairmen: *W. J. Scharfenaker*, Superintendent, Masonry Dept., Ford Motor Co., Dearborn, *and E. B. Snyder*, Refractories Engineer, Wheeling Steel Corp., Steubenville, Ohio

Progress Report on All-Basic Furnace: *J. E. Harrod*, Assistant to Div. Superintendent, Steel Production, South Works, United States Steel Corp., Chicago

Progress Report on Basic Construction: *A. H. Sommer*, Vice President and General Superintendent, Keystone Steel and Wire Co., Peoria, Ill.

Progress Report on Flat Basic Roof: *J. F. Pollack*, Superintendent, Open Hearth Dept., Jones & Laughlin Steel Corp., Pittsburgh

Progress Report on Flat Basic Roof: *Levi Yager*, Open Hearth Superintendent, Laclede Steel Co., Alton, Ill.

Progress Report on Flat Basic Roof: *P. W. Nutting*, Assistant Superintendent, No. 2 Open Hearth, Inland Steel Co., East Chicago

Progress Report on Sprung Basic Roof: *C. W. Cravens*, Assistant Director Manager, Republic Steel Corp., Cleveland

Panel Discussion Including All of Above

Cold Metal and Basic Foundry Session

9:30 am to 12:15 pm—Allegheny Room

Chairmen: *C. J. Petry*, Div. Superintendent, American Steel and Wire Div., United States Steel Corp., Worcester, Mass., *and K. P. Campbell*, Div. Metallurgist, Sheffield Steel Div., Armco Steel Corp., Houston

Quality Considerations in Cold Metal Charging at Worcester: *R. H. Farr*, Steel Works Div. Metallurgist, American Steel and Wire Div., South Works, United States Steel Corp., Worcester, Mass.

Alloy Steel Production in a Cold Metal Shop: *A. H. Stewart*, Plant Metallurgist, Washburn Wire Co., Phillipsdale, R. I.

Use and Economics of Basic Lined Runners: *Anthony Edwards*, Superintendent, Open Hearth, Keystone Steel and Wire Co., Peoria, Ill.

Mechanical Aids to Open Hearth Repairs: *M. H. Weir*, Superintendent, Masonry, Sheffield Steel Div., Armco Steel Corp., Houston

Advantages of an All-Basic Furnace in a Cold Metal Shop: *A. H. Sommer*, Vice President and General Superintendent, Keystone Steel and Wire Co., Peoria, Ill.

Operating and Combustion Session

2:00 to 5:00 pm—Ball Room

Chairmen: *P. G. Sammett*, Open Hearth Superintendent, Armco Steel Corp., Ashland, Ky., *and R. G. Phelps*, Superintendent, No. 3 Open Hearth, Inland Steel Co., East Chicago

New Trends in Firing Practices in the Open Hearth Furnace: *J. E. Goodin*, Combustion Engineer, Granite City Steel Co., Granite City, Ill.

Jet Atomization: *William Wood*, Open Hearth Practice Engineer, Campbell Works, Youngstown Sheet and Tube Co., Youngstown

Contribution of Bath Temperature Control to Improved Open Hearth Production Rates: *W. J. Flynn*, Assistant to Div. Superintendent, Steel Producing Div., Gary Works, United States Steel Corp., Gary

Influence of Open Hearth Combustion Practice on Rates of Heat Transfer as Determined by Use of the Hot Model Technique: *J. S. Richards*, Chief, Steel Processing Div., Applied Research Laboratory, United States Steel Corp., Monroeville, Pa.

Design and Operation of Open Hearth Furnaces in Australia, 1957: *R. L. Knight*, General Superintendent, Steel Production, Broken Hill Proprietary Co. Ltd., Melbourne, Australia

Physical Chemistry of Steelmaking Session

2:00 to 5:00 pm—Allegheny Room

Chairmen: *J. F. Elliott*, Associate Professor of Metallurgy, Massachusetts Institute of Technology, Cambridge, Mass., *and R. C. Madden*, Chief Metallurgist, Algoma Steel Co. Ltd., Sault Ste. Marie, Ont., Canada

Significance of C. H. Herty, Jr.'s Work to Modern Steel Practice: *G. R. Fitterer*, Dean, Schools of Engineering and Mines, and Director, Engineering Research Div., University of Pittsburgh, Pittsburgh

Current Concepts of Open Hearth Slag Control: *M. W. Lightner*, Vice President, United States Steel Corp., Pittsburgh

Reminiscences of Herty's Activity in Industry: *J. E. Jacobs*, Assistant General Manager, Lackawanna Plant, Bethlehem Steel Co., Lackawanna, N. Y.

Annual Fellowship Dinner

Tuesday, April 9

6:30 pm—Urban Room

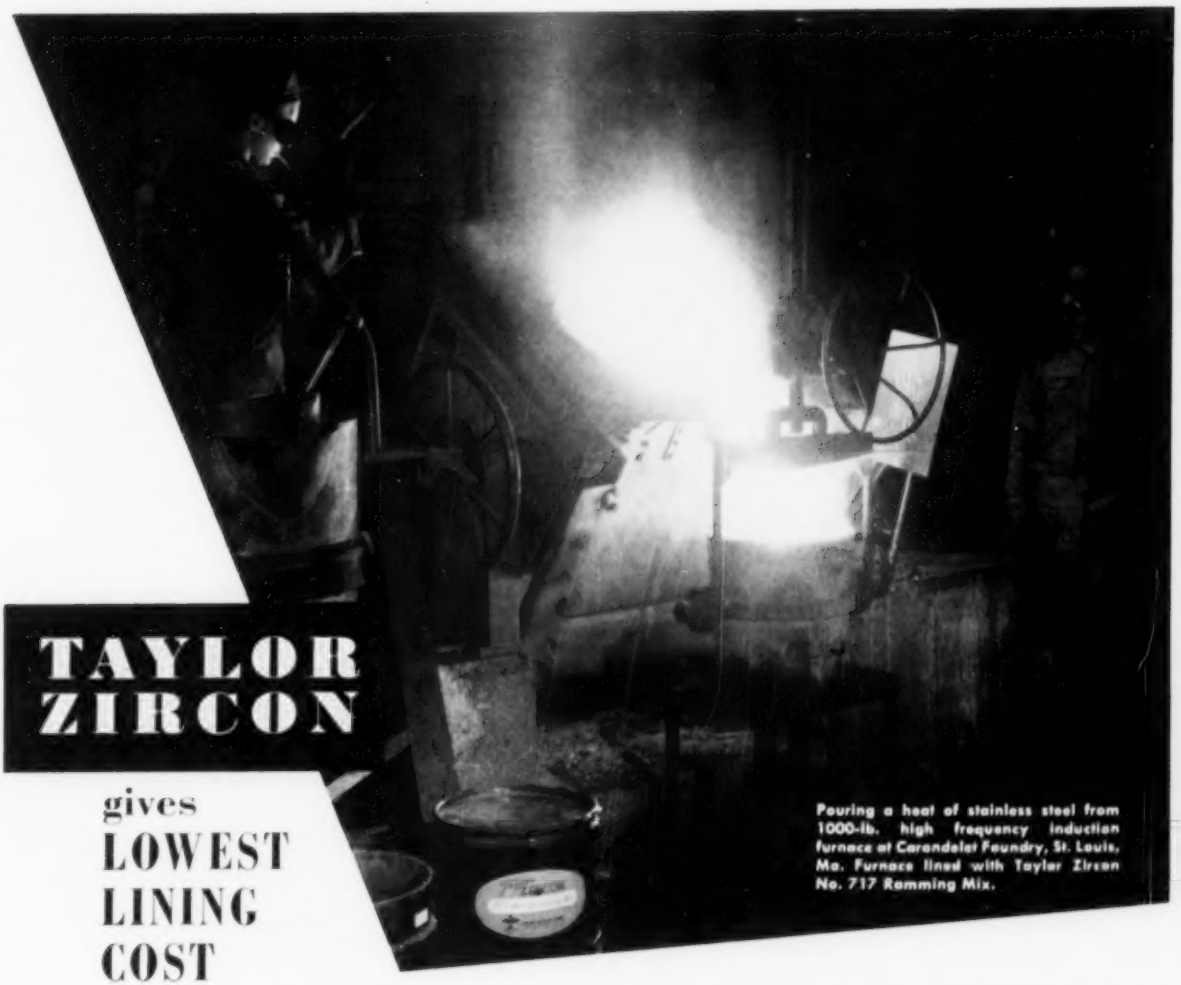
Reception and Cocktail Party for dinner guests.

7:00 pm—Ball Room

Annual Fellowship Dinner

Toastmaster: *D. R. Loughrey*, Jones & Laughlin Steel Corp., Pittsburgh

Speaker: *Major General John B. Medaris*, Chief of Army Ballistics, Missiles Agency, Redstone Arsenal, Alabama



Pouring a heat of stainless steel from 1000-lb. high frequency induction furnace at Carondelet Foundry, St. Louis, Mo. Furnace lined with Taylor Zircon No. 717 Ramming Mix.

TAYLOR ZIRCON

gives LOWEST LINING COST

for induction furnaces at Carondelet Foundry

Careful cost accounting at Carondelet Foundry, St. Louis, Mo., has shown Taylor Zircon No. 717 Ramming Mix to be the lowest cost lining for their two 1000-lb. high frequency induction melting furnaces . . . *less than ⅓ the cost* of previous lining materials used, as shown by their cost records, reproduced at left.

	TYPE OF LINING	
	Magnesia-alumina-spinel	Taylor Zircon No. 717 Ramming Mix
Representative No. of Heats	56 62	306 342
Total Lbs. of Metal Melted	42,796 47,835	304,837 310,130
Average Lining Cost per pound of Metal	$0.00755	$0.00220

This foundry melts a wide variety of steels, principally nickel-chromium and straight chromium stainless. Pouring temperature is 3300° F. In addition to the cost advantage, Carondelet finds there is less slag build-up with Taylor Zircon and the lining is readily cleaned.

If your foundry melts similar stainless steel alloys, it will pay you to test Taylor Zircon linings. Write us, or contact the Taylor field engineer in your area for detailed information.

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A Report on the State Of

by C. E. Reistle, Jr.

I FIND words inadequate when I try to tell about the wonderful experiences, new friends, and things I have learned about the mineral industries as President of the Institute. However, I feel somewhat like an older friend of mine who reluctantly took his first airplane ride with me. That night in the hotel room, he looked up and said, "You know, I think air transportation is here to stay." I have the same feeling about our Institute and engineering in the mineral industries. We are here to stay.

During the year I had the pleasure of visiting 36 Sections and Subsections extending from Alaska to Florida and from Boston to San Francisco; the fall meeting of the Petroleum Branch in Los Angeles; the Electric Furnace Steel Conference in Chicago; the joint meeting of the Colorado MBD Subsection and the Pikes Peak Section in Colorado Springs; the Rocky Mountain Minerals Conference in Casper; the Institute of Metals Division in Cleveland; meeting of the Pittsburgh Section and the National Open Hearth Steel Committee in Pittsburgh.

Frankly, this year I had very little idea how the other segments of the Institute actually functioned as compared to my own Gulf Coast Section and Petroleum Branch. Believe it or not, no two functions alike. In fact, there is very little similarity between them except for having a standard administrative setup. However, each functions in accordance with the wishes and needs of its particular members. Some are undoubtedly more effective than others. I am convinced that all can be improved and that the new national organization setup will provide for stronger Sections and greater service to the individual members.

It is my firm belief that the Local Sections are the most important part of our Institute. The three new Societies and the National Institute can only justify their existence by rendering a service to these Sections and their individual members.

Where AIME Stands

But before I discuss the organization and problems of the Institute, I would like to report on internal health of the Institute.

First, financially we have had a satisfactory year. The Institute has been able to carry on expanded activities much greater than ever before undertaken, such as more regional meetings and a larger volume of published technical papers, and, at the same time, has lived within its budget.

During 1956 the three Branches published in their journals 325 technical papers comprising 1600 pages. In addition, these papers will be published in the Transactions of each Branch.

Our year was also satisfactory from a financial viewpoint. Our total income amounted to $874,968 and our expenses were $860,856, leaving a surplus of $14,111. I might add that each Branch of the Institute operated within its income and contributed almost equally to the surplus of $14,111. Our endowment and custodian funds now amount to $1,552,684, an increase of $129,047. This represents the value of our investments at cost to us, and they have a greater value on the present day market.

Our interest in real estate and other assets of United Engineering Trustees is valued at $491,642. A more detailed discussion of these items can be found in the official AIME Annual Report.

Secondly, membership has grown at a remarkable rate. Much credit for this fine growth is due to the activities of our membership committee. During the year, our total membership grew from 26,548 to 29,713, an increase of 3,165 or 12 pct. The percentage loss in membership, excluding Student Associates, due to suspensions, resignations, and deaths is lower than any of the preceding three years and amounted to only 4.4 pct as compared to 5.4 pct in 1953.

It is estimated that there are 240,000 members in the professional engineering societies affiliated with Engineers Joint Council. Our membership constitutes 12.4 pct of this total. It is obvious that our membership represents a large segment of the professional engineers in this country.

Third, the number of Local Sections has increased from 69 in 1955 to 73 in 1956. As I mentioned previously, I feel that our Local Sections are the most important part of our internal organization.

Your Board of Directors this year has devoted its time principally to the consideration of two problems. The first and most important of these being a study of the Institute's organization. Secondly, a study of the problem of selecting a new headquarters site for the Institute and its fellow Founder Societies.

The New Structure

As a result of its work on the first problem, the Board on Sunday, February 24, adopted new Bylaws for the Institute. These Bylaws provide for the Institute to be divided into three Societies: the Society of Mining Engineers, the Metallurgical Society, and the Society of Petroleum Engineers. These Societies replace the three Branches of the Institute. In addition, the Board approved the Bylaws of each of these three Societies with the understanding that certain changes may be made in these Bylaws by the Board of Directors of the Institute from time to time either upon recommendation of the Society or the Board of Directors of the Institute in order to maintain an effective organization. It is clearly understood that the solution of any unanticipated problems—and I am sure that we will have some—must be approved by the Board of Directors of the Institute.

The new Bylaws also provide for continuation of the Council of Section Delegates, which was recognized as a strong and constructive force in Institute affairs. Provision is also made for a Council of Education and a Council of Economics, so that our vital interest in these two subjects can be given proper consideration.

I feel that this new organization can best be compared to a new plant, a new model automobile, or a new company—there are bound to be unanticipated problems. The future of the Institute depends upon how well we meet and solve these problems.

The Board of Directors also gave careful consideration to the selection of a new headquarters site. This problem was most difficult because it was necessary to

EDITORIAL

The Institute

(Presented at the Annual Meeting All-Institute Technical Session, Tuesday, Feb. 26, 1957, at New Orleans)

work with the other Founder Societies through the mechanism of the United Engineering Trustees, and select a site that was mutually acceptable to all. I would be remiss indeed if I did not acknowledge the generous offers and interest displayed by various groups of civic-minded people in New York, Pittsburgh, Philadelphia, Chicago, Washington, D. C., Shreveport, St. Louis, and Kansas City. Each of these cities paid the engineering profession high praise in offering to make substantial contributions to a new engineering center.

A New Headquarters

The responsibility of representing AIME on the special Task Committee of the Founder Societies and AIChE was placed in the hands of our most able and respected immediate Past-President, Henry DeWitt Smith; Harold Decker, a Vice President of the Institute; and Clyde Williams, also a Past-President. I cannot pay Henry DeWitt Smith too great praise for the outstanding leadership he displayed in reconciling the emotional and factual factors that were generated in the consideration of this problem.

This Committee had its first meeting on Oct. 10, 1955, and on June 22, 1956, brought in the following report:

► The Engineering Societies Center be located in New York City.

► The 39th-40th Street site be continued in use as the site of the Engineering Societies Center.

If rebuilding in that area proves impracticable, a comparable site should then be sought in midtown New York.

We suggest that the governing boards also adopt these further recommendations for inaugurating action:

► The United Engineering Trustees Inc. be authorized to take proper legal action for expansion by the addition of the American Institute of Chemical Engineers to the incorporators when properly qualified.

► The United Engineering Trustees Inc. be authorized to raise money and accept contributions; accept the offer of the Kelly Committee—quoting from Dr. M. J. Kelly's letter, his Committee made the following commitment: "We assure you that a well organized, diligent, and competent effort will be made and continued until the required sum is available"—place contributions in UET capital fund assets; employ architects, engineers, and attorneys; let contracts for reconstruction of the present Engineering Societies Building and/or a new building or buildings; pay all costs out of the capital fund assets; and operate and maintain the new Engineering Societies Center.

► The plans for the new and enlarged Engineering Societies Center be made with ample optimism with respect to the future growth of the five Societies immediately involved. These facilities should be such as to attract and hold all of the engineering profession, thus fostering unity and cooperation along the broad lines.

The Four Societies constituting United Engineering Trustees Inc. (AIME is one of these four Societies) approved the above recommendations by the end of September 1956. The American Institute of Chemical Engineers approved recommendations 1 and 2 and signified its desire to become a member-body of UET Inc. By the end of November 1956, UET and its four member Societies had agreed upon arrangements by which AIChE would become a member-body of UET Inc.

Progress, Plans, and Proposals

The first important problem facing UET was to determine the feasibility of developing the present building site on West 39th Street in cooperation with the Engineers' Club which faces 40th Street. Shreve, Lamb & Harmon Assoc. were retained as architects and they submitted two proposals at the end of November 1956. One proposal visualized razing the present structure and erecting a new building. The New York City setback ordinances made it impossible to carry out the plan satisfactorily and it was rejected. The second proposal visualized using more of the present building envelope but reconstructing the interior, enlarging and modernizing it, and erecting a building in access space to 40th Street on the assumption that the necessary land could be secured from the Engineers' Club. The proposal included two stages, the first providing 189,000 sq ft of net usable space on the present site and the Club land; the second adding 53,000 sq ft by taking additional property on 39th Street. This proposal was submitted to two reputable construction companies for cost estimates. The two estimates, received late in January, were very close, and revealed that the cost rehabilitation was so high that the use of the present site seemed unwise. The reconstruction would require moving out, thus adding additional costs of moving out, rent at commercial rates for from 1½ to 2 years, and moving into the rehabilitated building. These cost factors and the fact that the result would be a remodeled makeshift that would not provide an attractive reason for securing new funds were discussed at two meetings of UET Inc., and on Feb. 12, 1957, the trustees decided to abandon plans for the present site and to seek a new one. Active steps are under way to that end.

In June 1955, Dr. M. J. Kelley, president of Bell Telephone Laboratories Inc., organized a committee of engineering leaders in industry and education which offered to aid the new Engineering Center by raising construction funds. Upon the approval of the recommendation of the Task Committee, UET Inc. immediately invoked the aid of Dr. Kelly and his committee. Dr. Kelly responded by organizing his fund-raising program, which he hopes to have under way before summer. To do so, the site must be selected and firm floor space needs determined for the occupants of the present building and for other societies who wish to take space in the new building. The deadline for these determinations is Apr. 1, 1957.

(Continued on page 576)

Looking Ahead

Now, looking into the future, I would like to suggest that the Board of Directors and members of the Institute give careful consideration and take steps to accomplish certain objectives. First, I think it is imperative that each member of the Institute accept in a constructive manner the new organization. That we be tolerant and act with mature judgment in correcting and adjusting the organization so that we may continue to render maximum service to the individual member in his need for professional engineering knowledge and social contacts. That we dedicate ourselves to preservation of the national organization—AIME—so that we may perpetuate and provide dynamic national leadership for all engineers in the mineral industries.

Secondly, today we find many members of the engineering profession demanding that society give the engineer greater recognition. It has been my experience that each of us, either as individuals or acting collectively as companies or professional societies, receives recognition not as we demand but as we deserve. There is no doubt that many people know little or nothing of the professional engineer. In the first place, the word engineer is applied to so many kinds of people, from the fellow who tends the apartment house boiler to the man who drives the locomotive to the draftsman over the drawing board and on up. Small wonder that when professional engineers start to claim special status, the ordinary citizen cannot imagine what all the rumpus is about. Furthermore, almost any group can get together and call themselves this or that engineering society.

Here I would like to quote from a recent speech of my good friend, Dr. W. K. Lewis, Professor Emeritus, Massachusetts Institute of Technology.

> "However, the important thing is not what the public thinks about us, but what we think, or ought to think, about ourselves. From this point of view, I feel there are two vital matters in which we fail to measure up to full professional stature. The first of these engineering shortcomings is that, while recognizing our social responsibility in the public interest, we interpret that responsibility far too narrowly. Any group aspiring to full professional status must accept responsibility for leadership in every phase of its area of specialization. Thus, the physician is interested not only in the health of the patient, but in every sort of activity related to health, curative and preventive, public and private. Unfortunately, this is not true of engineers. For example, the production of goods has its human as well as its technical side. In technical matters the engineer is perfectly willing to be held accountable, but his attitude as an engineer is that the human phases of production are none of his business. If the engineer hopes to secure acceptance of his professional status, this attitude must change.
>
> Unfortunately, there is still further evidence that engineers are mere technicians. Medicine is fully as specialized as engineering, yet the medical profession has its great professional society, to which its organizations of specialists are subsidiary. We engineers, on the other hand, have our societies of civil and mechanical, of electrical and metallurgical, of chemical and aeronautical engineers. The only things that differentiate these groups are techniques. Our very organizations demonstrate our lack of breadth in professional outlook.
>
> Efforts have been made in the direction of correcting the situation, but they are feeble. We have our state and national societies of professional engineers, but these are merely associations of individuals licensed (registered) by the state, and such a license is the qualification for membership. We have the Engineers Joint Council, but this is too weak to speak with authority for the profession as a whole. Their organization bears about the same relation to what is needed as the Articles of Confederation between the Colonies bore to our American Constitution. If engineering is to get the general recognition it desires, it must first achieve for itself a sense of its own unity and give effective organizational expression to it."

Recognition for the Profession

The need Dr. Lewis points out has been obvious to many engineers for some time. ECPD must be given credit for initiating a movement to make a broad survey of the engineering profession in an effort to solve the problem. As a result, in January of 1956, EJC authorized a joint committee with ECPD to explore the question as to whether or not a survey of the engineering profession should be made.

This ECPD-EJC joint committee made the following recommendations in September 1956:

1) They endorse the proposed survey of the Engineering profession as outlined in their report dated September 1956.

2) They endorse the establishment of a joint ECPD-EJC committee on a survey of the engineering profession.

3) They recommend that funds be authorized for the initiation of the survey. Once solid support on the part of the societies is demonstrated, there is indication that other sources will provide substantial underwriting. An immediate subsidy of $50,000 from the societies is suggested.

Your Board of Directors has authorized an expenditure of $7500 as AIME's proportionate part of this proposed expenditure. It is estimated that it will cost on the order of $1 million and require at least two years to make a survey of the engineering profession.

The joint committee of EJC and ECPD suggests the establishment of "a committee on the survey of the engineering profession under the joint auspices of ECPD and EJC." I think it is time for us to recognize that the National Society of Professional Engineers, and I might add that I am not a member of this Society, is also a vital force in the engineering world. I would suggest that they also be included in this group effort or study.

But it is even more important, in my opinion, that the Board of Directors of the Institute take a definite and constructive part in this proposed activity. Furthermore, steps should be taken to keep the membership fully informed by regular reports in the journals of the Institute. One of the great weaknesses of EJC and ECPD in my opinion is that the rank and file members of the member societies have little or no knowledge of the plans or actions of these two organizations. On the other hand, the NSPE has *representation from the "grass root" level* and can act with force and knowledge of the entire membership.

I recommend that a strong and active Board committee be formed in our Institute to study, review, and guide our activities in ECPD and EJC. Also, that our representatives in these two organizations work in cooperation and under the guidance of this committee. Furthermore, this committee should keep the Board of Directors fully informed of their actions. In turn, the Board of Directors should provide a means of informing the Sections of their actions and obtain counsel from the Sections of the Institute. Perhaps there is a better way to do this, but I at least feel it is my duty to call the problem to your attention, hoping that as a result we can take full advantage of this proposed study. Otherwise, I am afraid that we will have another fine report about the engineering profession known only to a few, and completely ineffective due to absence of knowledge and understanding by the 240,000 engineers affiliated with us in the Engineers Joint Council.

by Michael O. Holowaty

and Charles M. Squarcy

Blast Furnace Coke Tested at High Temperature

Blast furnace operation has shown that certain cokes, even though possessing excellent tumbler stability and hardness test ratings, adversely affect production when reaching the highly critical tuyere zone. These discrepancies have led to the development of a high temperature compression test.

SEVERAL years ago experiments were conducted at Inland Steel to correlate coke performance in the blast furnace with the chemical and physical properties determined by the conventional tumbler stability and hardness tests.[1] The blast furnace itself[2-4] proved that certain cokes, even though possessing excellent test ratings, adversely affected production, particularly 6 to 8 hr after being charged. Obviously, the coke passing muster at room temperature was failing in the highly critical tuyere zone. The reduction of blast volume, which was normally done several hours after charging, indicated that coke was degrading somewhere above the tuyeres, thereby decreasing the volume of voids and consequently preventing the penetration of gas into the stock column.

Temperature and pressure appear as the most likely causes for decrepitation of the coke particles. Effects of abrasion and impact crushing, such as occur in the tumbler drum, were discounted since the burden, which at this critical stage consists of liquid slag, molten metal, liquid metal oxides, and solid coke, represents a gradually moving bed settling toward the hearth of the furnace. Therefore, **a high temperature compression test was designed to predict coke performance in the blast furnace.**

High temperature compression tests were carried out on cokes produced and used at the Indiana Harbor Works of Inland Steel Co. Tests were also made on several cokes purchased from outside sources, and correlations were made with actual blast furnace performance on each type of coke. Chemical and physical characteristics of cokes included in this program are given on Table I. Anthracite was included because of the interesting results obtained with this material in the investigation of the heating characteristics of bituminuous coals.[5]

Room temperature compression tests were conducted to determine the magnitude of pressures which would be required in the high temperature test, and all cokes were subjected to this test. Samples were prepared from pieces of various cokes and run on a Baldwin tensile machine. A cube with edges measuring approximately ⅝ in. was sectioned from each piece, precautions being taken to take samples from the center portion of the coke, in order to assure freedom from cracks and fissures. The raw sample was then carefully ground to a ½-in. cube of close tolerance. Results obtained in the cold compression tests are given in Table II.

The high temperature compression test.

High temperature tests were conducted at 3000°F in a nitrogen atmosphere. This is the approximate temperature which prevails in the zone just above the tuyeres—the most critical stage of the blast furnace process, where coke represents the only solid

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material of the burden, thus controlling the permeability, and hence the productivity of the blast furnace.

The tests were conducted in the apparatus shown in Fig. 1. An alundum sleeve is located between the graphite crucible and the original melting crucible to reduce thermal shock on the latter, since no liquid metal charge was used. The graphite crucible is provided with a heavy 3-in. thick graphite cover equipped with three holes. The large center hole—2 in. diam—is occupied by the pressure rod, and the adjacent ½-in. hole, drilled on an incline of 75°, permits temperature determination by an optical pyrometer. The cover is also provided with a small ⅜-in. hole to accommodate a porcelain tube delivering dry nitrogen to the system. The nitrogen duct is in the wall of the crucible, permitting nitrogen to be preheated prior to entering the sample chamber. The pressure rod is made of electrode-type graphite, and the leverage ratio is 1:2.64.

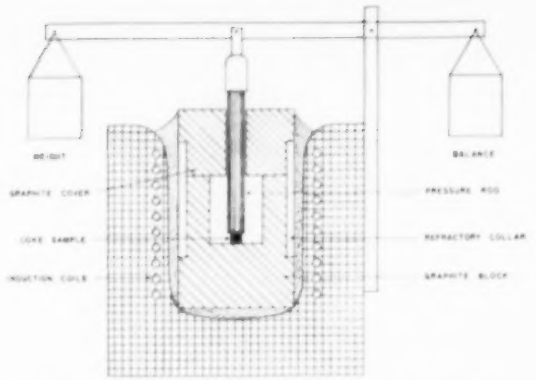


Fig. 1—Schematic diagram of experimental high temperature coke compression testing apparatus.

Testing Procedure: Test specimens are similar to those used in cold compression tests, except that the high temperature test cubes measured only ¼ in. Reduction of sample size is necessary because of the relatively high pressures required for destructive compression of coke. The specimen is placed on the bottom of the crucible, the graphite cover is placed on top of the crucible, and the space between the graphite assembly and the refractory melting crucible is filled with magnesia sand to reduce heat losses. The compression rod is then lowered and immediately counterbalanced with lead shot, so that no pressure is applied to the sample at any time prior to the actual compression test at 3000°F.

Nitrogen flow is started and the entire system purged for 4 to 5 min before the power is turned on. Nitrogen passes through concentrated sulfuric acid and a granulated desiccating material to dry it and strip it of the residual acid particles. After purging, the power is turned on and the temperature raised to 3000°F or slightly above, which takes 19 to 20 min. This temperature is maintained while pressure is increased by pouring lead shot slowly into the lever arm container. A sudden plunge of the lever arm indicates collapse of the sample, and the addition of lead shot is discontinued at once. The power is turned off, and the entire system is allowed to cool in the nitrogen atmosphere.

Test Results and Evaluation: Tests were made on at least four samples of each coke; their results are given in Table I. It might appear that these results are far beyond the values which coke would encounter in its downward travel in the blast furnace shaft. This would be true if the coke particles were cubes or other regular shapes neatly arranged within the furnace burden. However, metallurgical coke consists of particles of various sizes and shapes with sharp, jagged edges which expose relatively small areas to the weight of overlaying burden. This condition can easily produce pressures immeasurably higher than those which could be arrived at by mathematical analysis of the stresses and loads in the burden consisting of geometrically well defined shapes.

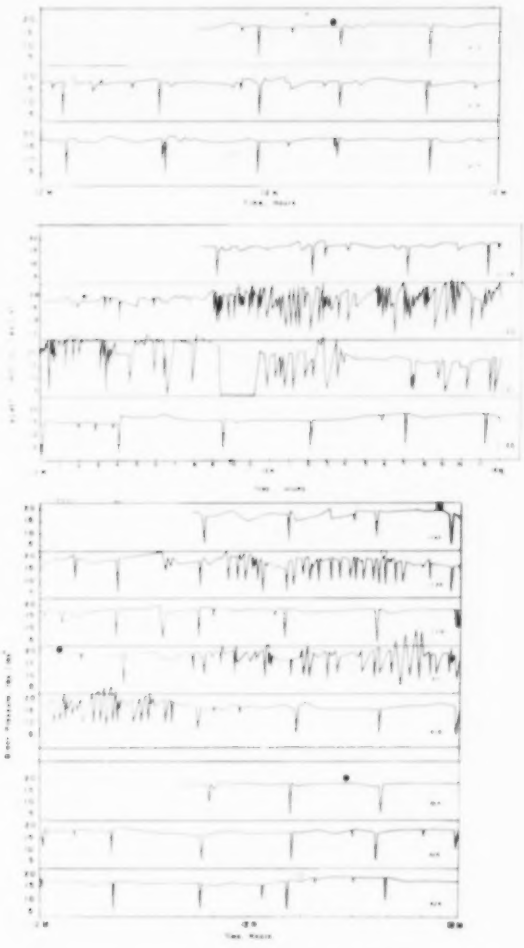
Compression strength indices of all cokes are higher at 3000°F than at room temperature. This increase was quite pronounced in all cases investigated. In addition, the standard deviation of results was consistently higher for the room temperature tests than for the 3000°F tests. This seems to indicate the existence of a process of homogenation which occurs when coke is heated to 3000°F in a nonoxidizing atmosphere. Structural and crystallographic changes of the heated cokes were not investigated, but it appears that cokes do undergo a definite process of crystallization in which the inhomogeneous carbon is transformed into graphite. This process is known also from investigations conducted recently abroad.[7]

Comparison of the data presented in Table I indicates that the high temperature strength is apparently not controlled by either the stability or hard-

Table I. Chemical Composition, Tumbler Test Results, and High Temperature Test Data of Experimental Coke Series

Coke Sample	Chemical Analysis, Pct			ASTM Tumbler, Pct		High Temperature Strength at 3000°F in Psi, Test Numbers						
	Vol Mat	Fix C	Ash	Stability	Hardness	1	2	3	4	5	6	Avg
1. Inland No. 2 Stand[a]	1.00	92.60	6.40	50.4	66.0	4685	4988	5081				4900
2. Inland No. 3 Stand[a]	0.60	93.20	6.00	54.3	67.4	5045	5639	5212				5300
3. Inland No. 2 Battery No. 4[b]	1.35	92.05	6.60	49.3	65.0	3901	4007	3222	4249			4050
4. Inland No. 2 Battery No. 6[b]	0.50	92.45	7.05	52.0	69.4	4325	4982	4325				4550
5. Coke *A*—By Product	0.75	89.65	9.60	48.9	64.1	5300	5088	5385	3159	3562	2926	(a) 5250 (b) 3200
6. Coke *B*—Beehive	1.30	90.65	8.05	28.3	55.8	3998	3617	4070				3900
7. Coke C—Beehive	1.20	89.60	9.20	47.6	57.8	1191	1073	1492				1250
8. Inland—25 pct Illinois[a]	2.30	90.60	7.10	54.9	69.3	3330	3600	3150				3350
9. Anthracite	8.10	80.40	11.50	6.7	—	5830	5750	6120				5930

[a] 35 pct Pocahontas, 65 pct Wheelwright Coal.
[b] 35 pct Pocahontas, 40 pct Wheelwright, 25 pct Illinois Coal (1955).



Blast furnace pressure charts for test periods. Fig. 2—(top) Chart for Period I using *H* coke. Fig. 3—(middle) Chart for Period II using *C* coke. Fig. 4—(bottom) Charts for Periods III and IV, using *A* coke.

ness characteristics of coke as determined by conventional means.

Blast Furnace Evaluation of Test Cokes.

The purpose of the high temperature tests was to predict the performance of the various cokes in the blast furnace.

Interest initially was centered on the so-called Inland-Illinois coke (Tables I and II, item No. 8), which was made from a blend of 40 pct Wheelwright, 35 pct Pocahontas, and 25 pct Illinois coal. Stability and hardness indices of this coke were slightly better than those of the standard Inland coke made with 65 pct Wheelwright coal and 35 pct Pocahontas (Tables I and II, items No. 1 and 2). High temperature compression strength tests, however, revealed that Inland-Illinois coke was considerably weaker at high temperature than the standard Inland coke and produced an index of only 3350 psi as compared to plus 4200 psi of the standard Inland coke. This would indicate that performance of this coke in the blast furnace would not be as good as that of standard coke. Operating results showed this to be true, for blast pressure on the furnaces burdened with Illinois coke began to rise 6 to 8 hr after charging and required a reduction of blast volume. This resulted in an overall production decrease of approximately 2.4 pct over a period of one month. The furnace returned to normal blast pressures and volume after changing to standard coke.

The reliability of the high temperature compression test was evidenced in the blast furnace performance data collected during four separate periods with the purchased cokes. Selection of the test period was based on burden data of individual furnaces, which at times included as many as six different cokes. In order to establish the effects of the specific cokes, an attempt was made to cut out periods during which the coke in question constituted the major fraction of the fuel burden.

Blast furnace No. 2 has a 19 ft diam hearth and a working height of 66 ft, while No. 3 blast furnace has a 17 ft 3 in. hearth and a working height of 69 ft 2 in. Using Inland coke with a high temperature compression strength index (HTCSI) of plus 4200 as a standard, individual test periods of the several cokes were compared as to index and performance.

Table II. Test Data on Cold Compression Tests of Selected Cokes, Psi

Number	Coke	Test 1	Test 2	Test 3	Avg
1	Standard Inland Coke	3480	2672	2588	2980
5	Coke *A* By Product	4340	4620	4380	4450
6	Coke *H* Beehive	1592	1748	824	—
7	Coke C Beehive	1288	1028	3020	—

Period No. I: *H* Coke (Beehive)—83.3 pct of the fuel burden in blast furnace No. 3, April 4–7, 1956, (HTCSI 3900 psi).

Operation was entirely smooth, and production was satisfactory, rising gradually in proportion with increasing volume of blast. No difficulties were encountered with burdening. Optimum production reached on April 6, (100 pct fuel burden) indicates that this coke is entirely satisfactory for the operation of blast furnaces.

Period No. II: C Coke (Beehive)—50 to 95 pct fuel burden in blast furnace No. 2, Jan. 20–22, 1956 (HTCSI: 1250).

Strong irregularity was experienced 6 to 8 hr after charging the coke into the blast furnace. Continuous kicking occurred, with pressure rising to above 25 psi. Plugging of blow pipes, which necessitated cleaning of blow pipes and changing of one tuyere on January 21, resulted in production loss of approximately 30 pct. Blast volume had to be gradually reduced from 54,000 to 44,000 cfm. Furnace returned to normal after replacing C coke with standard Inland coke, Plant No. 2.

Period No. III: Coke *A* (Byproduct). Average 61 pct of fuel burden on blast furnace No. 2, Jan. 22–31, 1956 (HTCSI: 3200 psi).

Operation was irregular about 10 hr after charging with the pressure building up gradually to approximately 22 psi. Furnace operated properly after this coke was withdrawn. Difficulties, including strong kicking, reoccurred on charging coke from the same shipment on Jan. 30, 1956.

Period No. IV: Coke *A* (Byproduct). Average 57 pct of fuel burden on blast furnace No. 2, Feb. 3–8, 1956 (HTCSI: 5250 psi).

Operation was smooth and production normal with tendency to increase after days when large amounts of *A* coke were charged. The coke appears to be entirely satisfactory for use in the blast furnace.

Discussion: Discrepancies between the high temperature strength tests and conventional ASTM tumbler tests are shown clearly by performance of beehive cokes in the blast furnace.

The *C* coke, having a tumbler stability index of 47.6 and a hardness index of 57.8, displayed a much poorer performance in the blast furnace than *H* coke, which had tumbler stability of 28.3 and a tumbler hardness of 55.8. Thus, performance cannot be indicated by tumbler stability and hardness indices, but performance might well be explained by differences in the HTCSI of *C* coke—1250 psi—and H coke—3900 psi. Judging from these considerations, it appears that neither the *C* coke (period II) nor the *A* low range coke (period No. III) are satisfactory substitutes for good metallurgical coke. The only investigated cokes which approach metallurgical coke quality are the *H* coke (period I) and one fraction of the *A* coke (period IV).

Variations in performance of the *A* coke are of particular interest, because the conventional testing methods offer no explanation for this phenomenon.

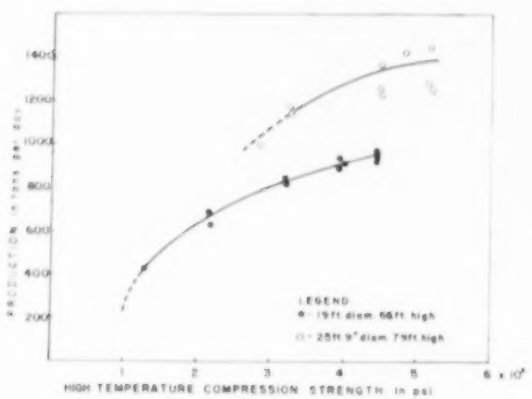


Fig. 5—Affect of high temperature coke strength on production rate of two Inland blast furnaces.

These experiments show that there is a high degree of correlation between high temperature strength properties and blast furnace output. In addition, two findings seem to support the concept of compression decrepitation of coke in the high temperature zone: 1) the first acting-up in the blast furnaces burdened with low strength cokes occurred from 6 to 10 hr after the change over, and 2) the amount of flue dust produced, and its carbon content remained essentially unchanged during the periods of burdening with weak coke. Point I indicates that the criterion for evaluating a given coke is its performance in the high temperature zone of the blast furnace which is normally reached in the indicated period of time. The absence of carbon increase in the flue dust produced during the inferior coke periods points also to a high temperature degradation of coke, in which the generated fines are quickly retained by the overlaying burden. If room temperature stability and hardness properties of coke were deciding factors, this would evidence itself clearly in the blast furnace operation by increasing amounts of flue dust containing high percentages of carbon from the upper reaches of the stack.

Significance of Experimental Results.

There appears to be a specific minimum level or HTCSI index range for satisfactory operation of a given furnace. Strength requirements are probably controlled by the design of the equipment, and the practice used at any given installation. Controlling factors include: a) height of the furnace burden, b) wind rate and blast pressure, c) size distribution of the ore burden, d) chemical and mineralogical composition of the ore burden, and e) average particle size of coke. This indicates that with a standard ore burden and blast furnace incorporating a constant volume of air per ton of hot metal, the height of the burden column and the size of the coke will be the critical factors governing the high temperature strength requirements for the coke.

Meeting the minimum requirements on high temperature strength of coke should assure trouble free operation of a given blast furnace at standard air volume per ton of iron produced. It appears that productivity of a given unit will increase up to an optimum with increasing high temperature compression strength indices. But the magnitude of the index of the optimum coke is not known and would be difficult to establish. From operational data of the No. 2 blast furnace, it can be deduced that the rate of increase above the minimum requirements would be much slower than the drop in the rate below the minimum strength values. The trend is indicated by the production data on two blast furnaces burdened with various cokes of known HTCSI indices, plotted in Fig. 5.

Factors Responsible for High Temperature Strength of Metallurgical Coke.

Inland's findings suggest that the following factors might appreciably affect the coke characteristics: a) volatile matter content; b) ash content, composition, and its fusion point; c) porosity and thickness of the coke cell walls; and d) internal cracking and fissuring within the coke body.

Volatile Matter: Content of volatile matter is of importance because a green, not fully degasified, foundry coke undergoes the process of carbonization during its travel in the furnace shaft and will, therefore, degrade much more rapidly than fully coked, metallurgical grade coke. It is, therefore, necessary to keep volatile matter as low as possible, preferably below 2 pct.

Ash Content: Similar reasoning applies to ash content, which should be kept as low as possible to prevent a mechanical collapse of coke at high temperature, since all mineral materials contained in coal have melting or fusion points below 3000°F. The maximum permissible ash content will vary, depending on the chemical composition of ash and the coking properties of the coals used in the coking blend.

Porosity and Cell Wall Thickness: Porosity and the thickness of cell walls was considered in order to establish relationships between performance characteristics and cell structures of the individual cokes. Representative pieces of various cokes were sectioned along the grain plane with a diamond saw, and the sections observed under microscope at 10X magnification. The study was made on cokes shown in Figs. 6-9.

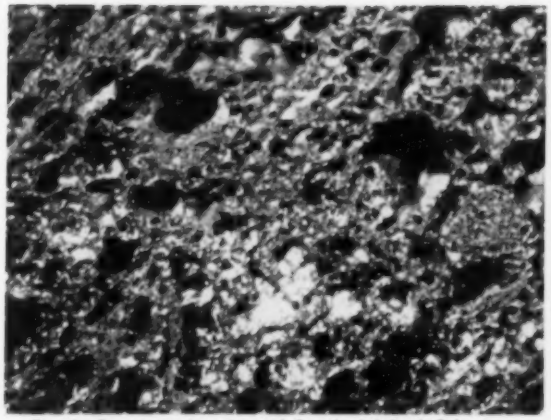


Fig. 6—Representative piece of Standard Inland Coke sectioned along grain plane with diamond saw and observed at 10X magnification.

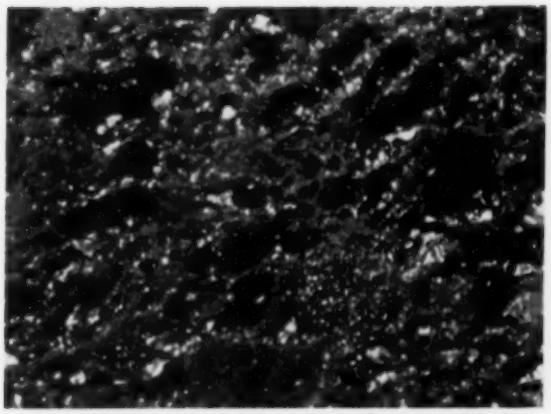


Fig. 7—Section of Inland No. 3 Plant (Pocahontas-Wheelwright) Coke at 10X. HTCSI of this coke was high and blast furnace performance was good.

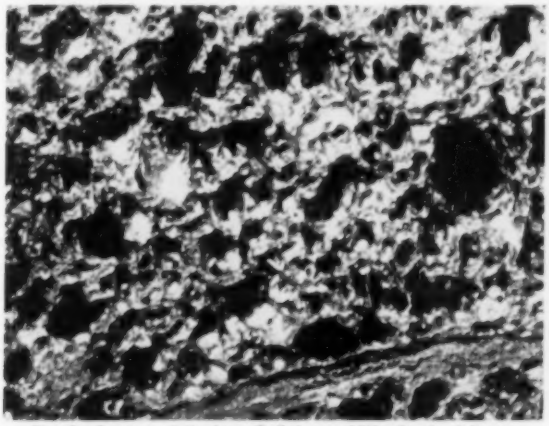


Fig. 8—Section of Beehive *C* Coke at 10X. Finely delicate lace work of this coke is considered at least partially responsible for poor blast furnace performance.

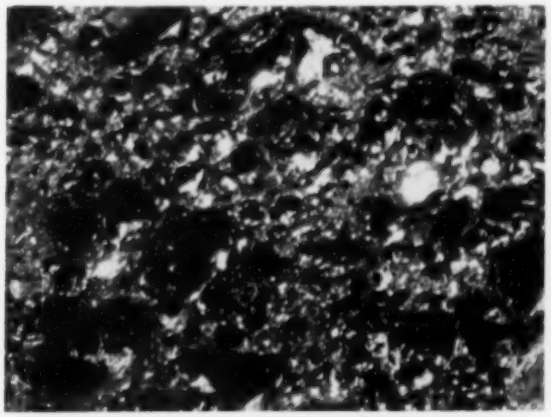


Fig. 9—Section of Beehive *H* Coke at 10X. Its strongly irregular void formation appears responsible for its high HTCSI and good performance.

These cokes show very marked differences in physical structures. The two cokes characterized by the highest and the lowest high temperature compression strength indices form two extremes in regard to the cell structure. The strong Pocahontas-Wheelwright coke, Fig. 7, shows voids of various sizes, evenly distributed throughout the body of the coke. The individual cells are surrounded by thick, apparently stable walls of carbonaceous matter. On the other hand, the C coke, Fig. 8, is characterized by finely delicate lace work or *suds*. It appears that the filigran structure of the *C* coke is at least partly responsible for its extremely poor performance in the blast furnace. The *H* coke is quite different; its void formation is strongly irregular and the structure contains rather large bubbles, as if produced by a pebbly, low volatile coal.

The reported observations have to be regarded for what they are—an attempt to find a clue to the high temperature performance of coke which is known to vary strongly from plant to plant and from coal to coal. Cell structure of coke is apparently one of the factors strongly affecting high temperature qualities. It appears desirable to produce coke built of relatively large cells surrounded by strong thick walls of carbon, This structure would satisfy two fundamental requirements demanded of blast furnace fuel—that of exposing large surface areas and withstanding the pressure forces and high temperatures in the critical zone of the blast furnace.

Structures made of suds-like formations and those made of apparently dense, low void formations are unsatisfactory, although the latter is probably to be preferred. It is, however, doubtful whether cell structure alone could be used for accurate determination of the blast furnace properties of a coke beyond the point of a preliminary visual examination.

Conclusions.

The high temperature compression test simulates conditions encountered by the burden in the high temperature zone of the blast furnace, and results appear to be satisfactory for predicting the relative performance characteristics of a given coke. While the ASTM indices satisfactorily indicate the handling properties of a given coke, they are inadequate for predicting its behavior in the blast furnace burden.

Microscopic investigations of the test cokes indicate a possibility of interpreting the properties of a given coke by means of cell structure.

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by R. J. Tatousek and A. T. Peters

An Evaluation of Cast Refractory Hot Top Linings

Use of cast refractory linings in C & D hot tops was discussed at the October 1955 meeting of the Technical Committee on Open Hearth Steelmaking of the American Iron & Steel Institute. While reports on performance were not conclusive, it was significant that many plants found the life of cast linings superior to brick.

A PRELIMINARY investigation at Inland Steel had shown that, although cast linings had nearly twice the life of brick linings, erosion of the cast lining during the extended life resulted in considerable increase in volume of the hot top. It was conceivable that the metal loss, which resulted from the increase in volume of the cast-lined hot tops, could offset the advantage of long lining life as compared to brick-lined hot tops.

Program for Evaluating the Performance of Regular and Reduced Volume, Cast Refractory and Brick Lined C & D Hot Tops.

C & D hot tops were used on 27¾-in., square, big-end-up molds. The average total ingot weight, using the regular and reduced volume hot top, was 12,500 and 12,200 lb, respectively.

Standard brick linings were made up of preformed segments, while the cast refractory linings were made up from a high alumina-silica aggregate of the nominal chemical analysis shown in Table I.

The aggregate was mixed with water to the consistency of mortar and tamped into a monolithic lining between the hot top casting and a grease covered, sheet steel form. After the refractory had set and hardened, the steel form was removed and the lining dried with a gas flame for about 48 hr.

R. J. TATOUSEK and A. T. PETERS are with the Inland Steel Co., Indiana Harbor Works, East Chicago, Ind. This paper is to be presented at the AIME National Open Hearth Conference, Pittsburgh, April 1957.

Table I. Chemical Analysis of Cast Refractory Lining Aggregate

Constituent	Pct
SiO_2	39.0
Al_2O_3	48.0
CaO	10.0
FeO	1.0
Balance	2.0

The reduced volume, cast refractory hot tops were obtained by using a sheet steel form with increased taper toward the top. The reduced volume, brick-lined hot tops were obtained by cutting standard lining brick face sections to a taper to give the same dimensions as the cast refractory, reduced volume hot top. The space between the brick lining and the hot top casting was filled with mortar made of burnt dolomite and cement.

The calculated volume of the reduced hot top, measured to the standard pouring height 4 in. below the top, was 15.5 pct less than the volume of the regular hot top. This reduction in volume effected a decrease of about 2.4 pct in total ingot weight. The original dimensions at the pour and bottom levels, the volume, and hot top metal weight for the regular and reduced volume hot tops are shown in Table II.

These experimental hot tops were maintained under normal operating conditions. Internal measurements of the pouring level and the middle level were taken frequently to determine the wear of the linings. Hot tops obtained from reduced volume and regular volume C & D hot tops are shown in Fig. 1.

Refractory and Installation Costs.

Refractory cost for the cast linings in regular and reduced volume hot tops was about twice the cost for

Table II. Comparison of Original Dimensions of Regular and Reduced Volume Hot Tops

	Regular Volume, Cast or Brick	Reduced Volume, Cast or Brick
Pouring level (4 in. below top), in.	18½x18½	15½x15½
Bottom level, in.	20½x20½	20½x20½
Original volume to pouring level, cu ft	4.5	3.8
Wt liquid metal in hot top, lb*	1950	1650

* Based on liquid metal weight of 435 lb per cu ft.

Fig. 1—Photograph of hot top obtained with reduced volume (left), and regular volume (right) C & D hot tops. Ingot molds are 27¾ in., square BEU. Hot tops were poured to a 20 in. height.

brick linings. Preparation and installation costs for cast linings were also greater than for brick linings.

It was difficult to clean out the old cast refractory linings from the hot top castings preparatory to installing new linings. In some instances an air hammer and chisel were required to break out the monolithic mass. Old brick linings were broken and removed easily with a pry bar.

Further, it appeared that the installation of cast linings would not lend favorably to relining maintenance. To expedite the relining procedure at normal pit operating rate, groups of hot tops would have to be relined at one time, due to the lining technique and additional materials required. With brick linings, single hot tops can be relined as required, permitting the use of a minimum number of hot top castings in service.

Increase in Hot Top Volume.

Accurate calculation of the volume change of the hot tops during lining life was difficult, since the surface of the linings did not wear evenly. It appeared reasonable, however, to assume the hot top volume as being proportional to the average cross-sectional area at the pour level and middle level.

Fig. 2 shows the percent increase in cross-sectional area over the original area at the pouring level and middle level, compared to lining life. The top and bottom levels have not been plotted, since the dimensions at these levels did not change from the original—the top level not being exposed to liquid metal, and bottom level being maintained to the original dimensions by the use of the hot top sealing ring and hot top compound mix.

For Regular Volume, Cast Lined Hot Top: Fig. 2a shows that the area of the pouring level and middle level of the regular volume, cast lined hot tops increased rapidly from the original cross-sectional area after about 75 heats. At a lining life of 120 heats, the average increase in cross-sectional area at the pour level and middle level corresponded to a volume increase of nearly 15 pct over the original volume.

It is significant in considering an optimum volume increase during the life of the cast lining, that when the volume increased to approximately 5 pct over the original volume, metal losses from the additional metal displacement in the hot top became excessive. For example, it is estimated that when the volume of the regular hot top increased 15 pct over the original volume, the hot top metal weight increased 300 lb. It is apparent that continued use of the hot top after 75 heats, throughout an average pour life of 120 heats, would lead to accumulated hot top metal losses exceeding 13,500 lb. The advantage of increased lining life would be offset by volume changes exceeding the optimum volume increases after 75 heats.

For Reduced Volume, Cast Lined Hot Tops: As shown in Fig. 2b, the erosion of the cast lining in the reduced volume hot top was almost equivalent to that of the regular volume hot top cast lining. It is significant that the erosion at the pouring level was greater than at the middle level as compared to the regular volume cast lining. Since the original volume of the reduced volume, cast lined hot top was 15.5 pct less than the regular volume hot top, the increase in hot top weight per pour was proportion-

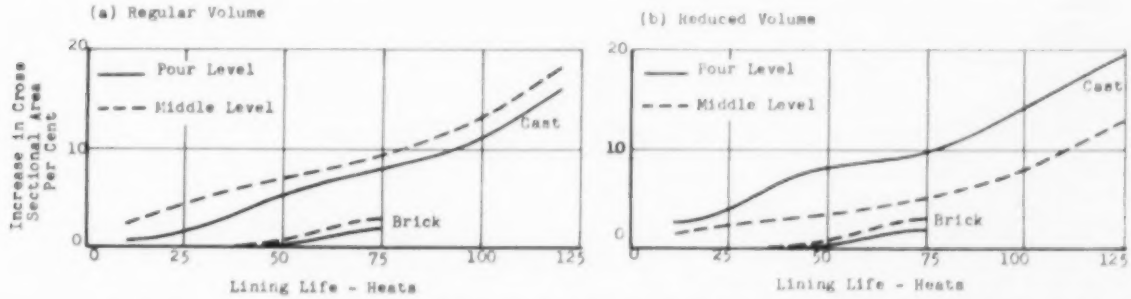


Fig. 2—Curves showing the erosion of cast and brick hot top linings during lining life, for regular and reduced volume hot tops.

Table III. Increase in Hot Top Volume and Weight for Cast Refractory and Brick Lined Hot Top

Lining	Description	Avg Pours	Increase from Original	
			Volume, Cu Ft	Wt Liquid Metal, Lb
Cast	Reduced volume	100 Optimum 140 Total	0.60 1.10	250 500
Cast	Regular volume	75 Optimum 120 Total	0.43 0.67	200 300
Brick	Reduced volume	75 Total	0.22	100
Brick	Regular volume	75 Total	0.20	90

ately less up to about 100 heats. This appeared to be the optimum in lining life and nominal increased hot top weight for the reduced volume, cast lined hot top. Although not shown in Fig. 2b, at the average lining failure of 140 heats, the increase in cross-sectional area of the pour and middle level was equivalent to a volume increase of nearly 30 pct of the original volume. This corresponded to about a 500 lb increase in hot top weight over the original reduced hot top weight of 1650 lb.

Compared with Brick Lining: As indicated by the lower pairs of curves in Fig. 2a and 2b, brick linings in the regular and reduced volume hot tops had less erosion than the cast linings. The increase in volume at the end of the average lining life of 75 heats was less than the optimum value of 5 pct of the original volume. This represented a hot top weight increase at lining failure of less than 100 lb. In addition, the hot top weight advantage effected by the reduced volume, brick lined hot top was sustained throughout the lining life.

The increase in hot top volume and weight for the optimum lining life, and total lining life for the cast refractory and brick lined hot tops are shown in Table III.

Table IV. Comparison of Weight of Hot Tops and Original Ingot Weight

	Pct of Original Ingot Wt					
	Regular Volume Hot Top			Reduced Volume Hot Top		
	New	End of Life	Erosion	New	End of Life	Erosion
Brick Lining	15.5	16.3	0.8	13.5	14.3	0.8
Cast Lining	15.5	18.0	2.5	13.5	17.7	4.2

The significance of the increased hot top weight, resulting from erosion, for the regular and reduced volume hot tops is shown in Table IV. During the life of the brick linings, metal losses resulting from erosion in both the regular and reduced volume hot tops averaged 0.8 pct of the original ingot weight, while for the cast linings, metal losses for the regular and reduced volume hot tops averaged 2.5 and 4.2 pct respectively. It is apparent that longer life of the cast linings did not favor economical performance.

Makeup of the hot top linings with hot top compound accounted for some flexibility in maintaining the original hot top volume. However, there were critical limits with regard to the thickness of the layer of compound applied, since drying was affected by heat retained in the hot tops. It was found that supplemental drying mediums would be required if the thickness of the compound exceeded a hot top volume change greater than 2.0 pct of the original volume. Hot top compound applied in heavier thickness led to boils and eruptions of liquid metal in the hot top. Such reactions contributed to safety hazards and poor metallurgical quality.

Observations indicated the main cause for hot top lining failure was due to the deterioration of the refractory. Cast refractory and brick linings weakened at about 100 and 60 heats, respectively. Failure resulted when sections of the lining, particularly in

Prepared Discussion on Cast

Cast Refractory hot tops at Ford showed increase of 22 pours over hot tops made with refractory shapes.

AT Ford, experience with cast refractory hot tops has been somewhat different from that of Inland Steel Co. When, in January 1956, trials began with a monolithic lining from an aggregate comparable to that used at Inland, Ford was averaging 38 pours per top before relining was necessary. Only one size hot top was being used for a 24x26-in., big-end-up mold, producing an ingot of 10,800 lb.

The first trial with a monolithic lining consisted of 53 hot tops. Total pours averaged 60.58 per top before excessive erosion took place. This increase of more than 22 pours per top led to further investigation, and the next 145 cast hot tops averaged 63.4 pours before being relined. It was decided to investigate also the reduced volume hot top.

Hot top volume was reduced from 15.2 to 14 pct. Steel quality at this level was comparable to the refractory lining previously used, and no abnormal conditions, such as increased pipe, segregation, or inclusions, were experienced.

Labor Costs Reduced.

When using the hot top made up with refractory shapes, one bricklayer and one helper were required on the day shift to make new tops. These two men were in addition to the seven hot-top men divided between the three shifts. During this period some 15 pct of production was bar steel of forging quality grades. At present, with 5 pct of ingot tonnage as bar steel and with use of cast refractory hot tops, a total of five laborers are employed. New hot tops are cast on the day shift where three of the five men are employed.

Repairs to cast hot tops consist of dressing them with a slurry, some patch work, and setting new refractory rings and wiper strips. To date, little difficulty has been encountered in removing old linings. This may be due partially to the fact that the thicker sections are removed by taking the tops down before they are excessively thin. Usually a pry bar and hand chipping tools suffice.

On the average, about seven new hot tops are cast per week at Ford. One hot top requires 275 lb of material, which is mixed in a mortar box with water to the desired consistency. Before the hot top casting is placed over a sheet steel form, all voids in the

Table V. Metallurgical Performance of Regular and Reduced Volume Hot Tops

	Regular Volume		Reduced Volume	
	Brick	Cast	Brick	Cast
Heats	120	60	60	60
No. deep etch tests	180	120	60	120
Internal soundness rating, pct of tests				
Porosity	0.0	4.0	0.0	4.8
Inclusions	0.6	0.8	0.0	1.6
Light welded pipe	2.8	0.0	1.7	0.8
Total retests required, pct of tests	3.4	4.8	1.7	7.2

the bottom portion, fell out of place during stripping operations and in handling while making up the hot tops. Whether or not this weakening effect is associated with mineralogical changes in the refractory has not been determined.

Practicability of Using Reduced Volume, Brick-Lined Hot Tops.

Inasmuch as the reduced volume, brick lined hot top proved practicable with regard to open hearth operating requirements, it was important to evaluate the metallurgical performance of the ingots poured with the experimental hot top.

Steel specifications included in the program consisted of about 40 pct intermediate manganese grades (0.15 to 0.23 pct C and 1.1 to 1.5 pct Mn), 40 pct forging grades (0.10 to 0.50 pct C and 0.40 to 1.0 pct Mn), and the remainder spring steels and several grades of resulfurized Ledloy. Double burnt dolomite was used as a hot top insulation covering.

At the blooming mill, a full cross-section test was cut from the top of the top prime product on the experimental hot topped ingots and the adjacent regular hot top ingots. All tests were taken from 2.5 to 4.0 pct of ingot height below the hot top collar. Cuts over 3 pct were necessitated by collar cracks and fins. Metallurgical performance was evaluated on the basis of the visual comparison of test sections after deep etching. All ingots were rolled bottom first.

Deep etch tests showed like performance for the slab or bloom product rolled from the reduced and regular hot top ingots, regardless of the specification or section size. Overall deep etch rating performance for the regular and reduced volume hot top ingots is shown in Table V.

On those ingots requiring retesting, a further cut of approximately 1.5 pct resulted in sound steel. All remaining tests were rated as showing a trace of center segregation, which is the normal rating for the top tests cut at the blooming mill. It should be noted that only cast linings showed tests with porosity.

It was concluded that the experimental reduced volume, brick lined hot top fulfilled requirements of application for all hot top steel grades made currently at Inland Steel.

Summary

The results of a program carried out for the purpose of evaluating the performance of cast refractory and brick linings in C & D hot tops, showed several features of operating and metallurgical importance.

Cast refractory linings were more difficult and costly to install than brick linings. Although the life of cast linings was superior to brick linings, excessive erosion during the extended life of the cast linings caused hot top metal losses which were prohibitive.

A brick-lined hot top reduced in volume to effect a decrease of 2.4 pct in total ingot weight as compared to the regular hot tops proved practicable with regard to operative and metallurgical requirements.

Refractory Hot Tops

by H. W. Clark
of Ford Motor Co.

casting are filled with a light weight, flake-type insulating material. This assures easy removal of the lining after it is no longer serviceable. The form is greased to permit free removal from the top after casting, and the aggregate is tamped into place. Three $\frac{1}{4}$-in. holes are then placed in each of the four sides of the casting from top to bottom. Vent holes are made 1 hr after ramming.

The new hot top lining is allowed to cure on the form for the next 16 hr. Actually, this could be accomplished in 8 hr, but no hot top crew is employed on the midnight shift. After the top is removed from the form, it is allowed to air dry for an additional 16 hr before heat is applied; the top is then placed on the drying deck. It was found that an efficient dry could be achieved by stacking three hot tops, chimney fashion over a $\frac{1}{2}$-in. gas jet, with a 1-in. air space between the tops for sufficient combustion. A slow fire is maintained for 4 hr, followed by maximum firing for the next 6 to 8 hr. The hot tops are then ready for use.

Hot tops down for reline reduced by 45 pct.

Due to the physical layout of the Ford plant and the stripping facilities for bar steel, there are certain restrictions on handling practices that limit the advantages which can be achieved. However, since using the castable monolithic top, the total number of tops down for reline weekly has been reduced by 45 pct.

Replacement and repair of hot top castings has been practically eliminated. This can be attributed to greater ease of stripping the tops from the ingots. The use of thicker hot top lining has added to the insulating value of the top and contributed to less pipe at desired yield levels.

Castable replacement costs are 40 pct less than costs incurred using refractory shapes, due to the elimination of skilled labor required to brick the tops, a greater utilization of existing nonskilled labor, and increased hot top life. Since tops are removed from service before the hot top lining becomes excessively thin, metal loss is no greater than when the tops were lined exclusively with refractory shapes. Comparison of past and present heat size with ingot tons poured gives a fairly close check of this condition.

Since the average top life was lower at the Ford plant than at Inland, the increase in hot top life with lower labor costs makes the use of cast refractory hot tops most attractive.

by A. M. Squires and C. A. Johnson

The H-Iron Process

For over 12 years, Hydrocarbon Research Inc., has studied the direct reduction of iron ore fines with hydrogen in fluidized beds, operating at temperatures below 1000°F, and at pressures above 200 psig. In conjunction with Bethlehem Steel Co. a demonstration-scale direct-reduction plant has been put in operation in Trenton, N. J. Experience with this plant has provided information necessary for construction and operation of a commercial direct-reduction facility.

INITIAL studies were directed toward manufacture of a powdered iron catalyst from a mixture of hydrogen and carbon monoxide for use in synthesizing gasoline. In 1950, a direct reduction plant of 20 tpd capacity was put on stream at Brownsville, Texas, to supply catalyst for a synthetic gasoline operation. Experience with this catalyst plant and with the large synthetic gasoline reactors at Brownsville, delineated the principle outlines of a direct reduction process for use in the steel industry.

During the past four years, in conjunction with Bethlehem Steel Co., a demonstration-scale, direct-reduction plant has been operated in Trenton, N. J. The plant can reduce a batch of 5 tons of ore in about 8 to 12 hr; it has produced more than 600 tons of reduced iron. The reduction step is generally conducted at about 900°F, and the pressure is about 250 psig. Experience with this plant has provided all of the background required for construction and successful operation of a commercial, direct reduction facility. Hydrocarbon Research and Bethlehem Steel have named their process the *H-iron* process, and the product is called *H-iron*.

A. M. SQUIRES and C. A. JOHNSON are with Hydrocarbon Research Inc. This paper is to be presented at the AIME Blast Furnace, Coke Oven, and Raw Materials Conference, Pittsburgh, April 1957

Principles of the process.

Fig. 1 illustrates the flow of solids through the process. Iron ore fines are first dried and preheated to about 900°F. A rotary kiln or a shaft furnace may be used for this step. The dry, hot ore is transported pneumatically to a bin located above a charge hopper. The charge hopper is first filled with a batch of ore and is then pressured with hydrogen to about 100 psi higher than the reducer. To transfer a batch of ore from charge hopper to reducer, the operator has simply to open the valves in the line shown between the two vessels. Iron ore fines flow through this line at their settled density; this type of flow is termed *dense-phase transport*. Solid line velocities are low, erosion problems non-existent, and line capacities extremely high, 5 tons of ore being transferred in about 15 min through a

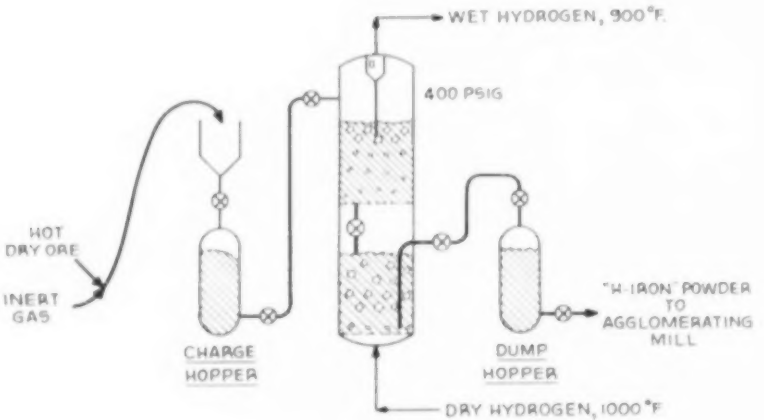


Fig. 1—The flow of solids through the H-iron process. In the reducer iron oxide reacts with hydrogen to form iron and water. Several batches of ore may be reduced at once in a series-type arrangement.

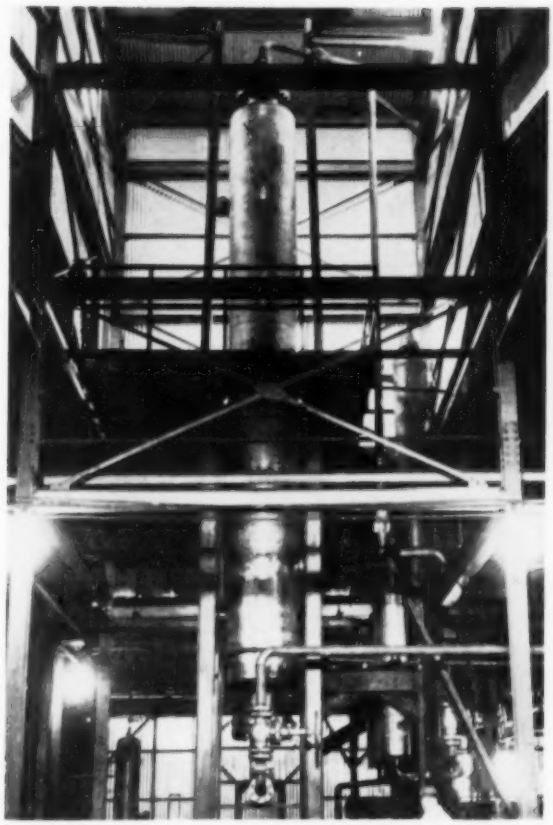


Fig. 2—This is the iron ore reduction vessel before insulation was applied. Iron ore fines are fluidized by hydrogen at low reduction temperature and elevated pressure.

Sched .80 $3/4$ in. line. The reducer vessel remains at full pressure during the transfer, and the flow of hydrogen through the reducer is not interrupted.

In the reducer, hydrogen reacts with iron oxide to form iron and water:

$$Fe_2O_3 + 3\,H_2 \rightarrow 2\,Fe + 3\,H_2O$$

Fig. 2 is a photograph of the reducer vessel at Trenton before insulation was applied. Fig. 3 shows typical reduction rate curves which are practicably attainable in the *H-iron* process.

Dry hydrogen is introduced at the bottom of the reducer and caused to flow up through the bed of iron ore fines. The hydrogen velocity through the bed is adjusted to a rate higher than that at which the iron ore fines are just buoyed up by the rising gas stream. The interstices between ore particles cannot increase much beyond their size when the ore bed is in the settled state; only a limited quantity of hydrogen can flow through these interstices, and so a large portion of the rising gas stream passes through the bed in form of bubbles. These bubbles produce violent agitation and stirring of the bed, and bubbles breaking from the surface of the bed makes it appear to boil. Bubbles are relatively small at the bottom, but they have a tendency to grow throughout the height of the bed. The situation is not unlike a pool of liquid undergoing violent aeration.

Special devices required to calm fluidized bed.

Growth of bubbles rising through the fluidized bed of iron ore fines presents a serious design problem. If their growth is unchecked, the reduction vessel would heave and *bump*. Carryover of fines, due to splash from bubbles breaking the surface, would be excessive, and the efficiency of gas-to solid contact would be very low. Devices have been developed to calm the fluidized bed of iron ore fines. Without such devices, commercial operations in a vessel of large diameter would be impossible, unless bed depths were sharply limited, and reduction rates obtained in large vessels would be orders-of-magnitude lower than rates obtained in reactors a few inches in diameter. At the bed depths required to secure good conversions of hydrogen to water when the reduction reaction is carried out under pressure, use of bed-calming devices are essential to economic success.

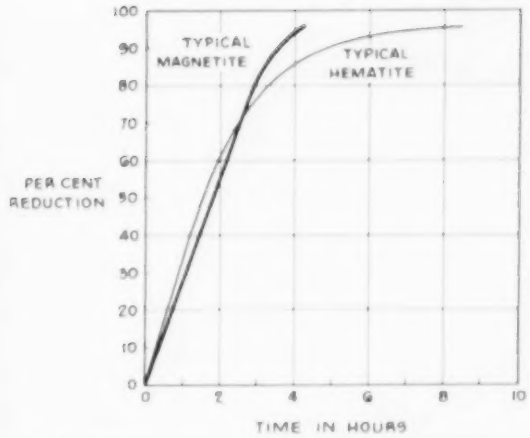


Fig. 3—Reduction rates practicably attainable in the H-iron process.

At the end of a reduction batch, reduced iron powder is transferred by dense-phase transport to a dump hopper, and the reducer is ready for another batch of ore. *H-iron* powder is compressed into chips, and Fig. 4 is a photograph of such chips manufactured from a Swedish magnetite ore.

Dust recovery proves efficient.

Dust recovery equipment is simple and extremely efficient; no fines whatsoever can be detected at the suction of the gas recycle compressor. After many thousands of hours of operation it may be reported that erosion of lines, valves, and equipment by iron ore dust and iron powder is not a problem. Techniques of charging and dumping the iron ore reducer have proven entirely reliable. Charging and dumping are carried out without depressuring the reducer or interrupting the circulation of hydrogen. Charging and dumping systems have given trouble-free service during hundreds of turnarounds between reduction batches.

Hydrogen gas circulating system.

Fig. 5 shows the essential features of the hydrogen gas circulation system. Dry hydrogen is heated in a furnace to about 1000°F and fed to the reducer. Wet hydrogen leaves the reducer at about 900°F, the temperature drop supplying heat leak and endothermic heat of the reduction reaction. Wet hydrogen is cooled by heat exchange with dry hydrogen and is further cooled in a gas cooling tower by direct contact with cooling water. Cooling the gas to 100°F serves to condense nearly all of the water from the wet hydrogen stream. Upstream of the gas cooling tower is a venturi scrubber for removal of

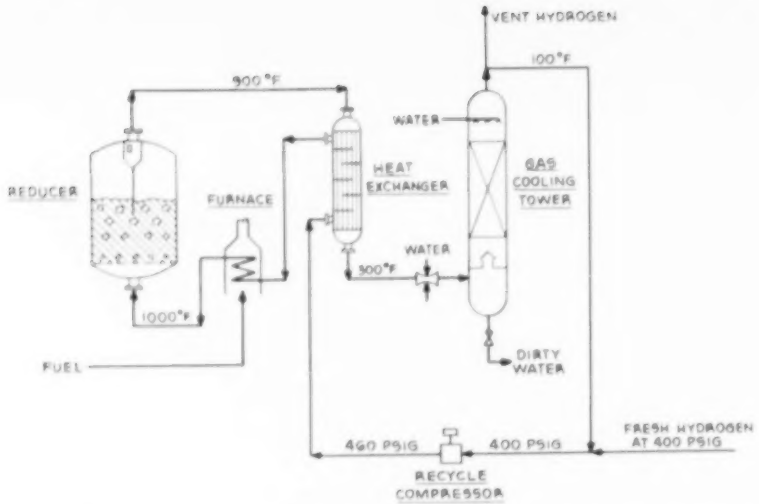
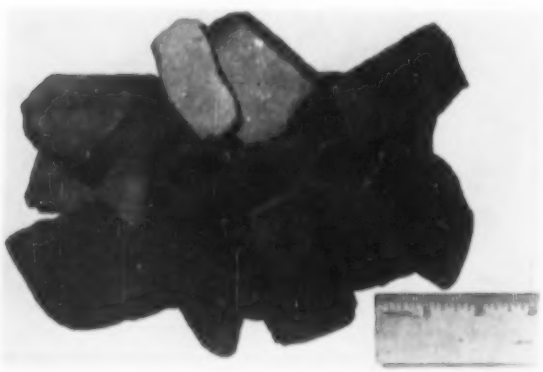


Fig. 5—(Right) The hydrogen circulating system in the H-iron process. Dry hydrogen heated to about 1000°F enters the reducer. Wet hydrogen from the reducer is dried by cooling to 100°F.

Fig. 4—(Below) Following reduction, H-iron powder is compressed into chips, such as this one made from Swedish magnetite.



iron ore fines. Dirty water from the scrubber, together with water produced in the *H-iron* reducer, is removed from the process. A small stream of hydrogen is vented to control the concentration of inerts in the circulating hydrogen stream, fresh hydrogen is added, and a recycle compressor boosts the stream to overcome pressure losses in the system.

Fig. 6 shows typical curves which are attainable in the conversions of hydrogen to water in the *H-iron* process. The conversion for a hematite is higher than for a magnetite at the beginning of a batch, but the magnetite ore gives higher conversions toward the end of a reduction batch.

Declining conversion rate creates design problem.

The decline in conversion as a reduction batch proceeds creates a design problem, since the process supplying hydrogen to the *H-iron* reduction circuit cannot readily be adjusted to give wide variations in hydrogen production rate over short periods of time. The solution to this problem is to carry out several reduction batches at once, in series, as shown in Fig. 1. When the batch in the bottom bed of the reducer is finished, it is dumped, and the contents of the upper bed are dropped into the bottom bed. A new batch of ore is then charged to the top bed. The rate at which water is produced is thereby made reasonably steady, so that excessive losses of hydrogen due to venting are not incurred. An *H-iron* plant is a continuous water producer, although charging of iron ore and dumping of iron product is intermittent. In this respect, the *H-iron* operation resembles a blast furnace, which is blown with air continuously, but it is tapped and charged with solids intermittently. The number of batches which must be processed simultaneously depends upon the characteristics of the ore and the reduction degree desired, but usually only two beds will be required.

Advantages of the H-iron process.

Use of low reduction temperature: Reduction temperatures are well below temperatures at which reduced iron powder becomes *tacky*. The *H-iron* process avoids troubles due to bed sticking and loss of mobility which have plagued many attempts to develop direct reduction processes. At the temperatures employed, expensive high-temperature refractories are not required, and periodic replacement of refractories is not necessary.

Use of elevated pressure: Elevated pressure is specified for two reasons: a) To promote high reduction rate at the low temperature required to avoid *tackiness*; reducer volume is comparable to blast furnace volume, although temperatures are 1800°F below temperatures of blast furnace discharge; b) To permit cheap drying of hydrogen leaving the reducer, simply by direct contact with circulating water. At 400 psig, hydrogen can be dried by 95°F water to a dewpoint of 9°F, that is, to a water vapor content of 0.2 mol pct. Hydrogen dried at atmospheric pressure by 95°F water would contain up to 5.4 mol pct water vapor.

Introduction of endothermic heat of reaction by gas stream: In the *H-iron* process, heat of reduction is supplied to the reducer in form of sensible heat of the circulating gas stream. At a hydrogen-to-water conversion of around 10 pct or less, the circulating gas stream is of a size such that it need not be heated to a very high temperature in order to supply the required endothermic heat. Higher conversions attainable at temperatures around 1200°F to 1800°F have proved of no use, because means employed to introduce heat were either expensive or unreliable.

Use of hydrogen as reductant: At the temperatures and pressures of the *H-iron* process, carbon monoxide cannot be used in mixture with hydrogen as reductant, because it is quantitatively converted to methane under *H-iron* reduction conditions. Inability to use carbon monoxide is not a disadvant-

age, however, for in any direct reduction process, the carbon initially present in fuel charged to the process must be removed as carbon dioxide. In the *H-iron* process, carbon monoxide is converted to hydrogen and carbon dioxide by reaction with steam in a shift converter:

$$CO + H_2O \rightarrow H_2 + CO_2$$

Carbon dioxide is subsequently scrubbed out of the hydrogen stream before it is sent to the *H-iron* reduction section.

In a high-temperature direct reduction process operating at 1200°F or higher, any carbon monoxide fed to the reducer will be partially converted to carbon dioxide; and such carbon dioxide must subsequently be scrubbed out of the entire circulating stream of reducing gases. This is more expensive than scrubbing carbon dioxide from hydrogen fed to the reduction circuit, and relatively pure hydrogen is the preferred reductant even in a high-temperature reduction process.

Use of iron ore fines: Advantage is taken of techniques developed during the past 15 years, primarily by the petroleum industry, for inexpensive processing, conveying, and handling of fine powders. Iron ore fines may be charged and withdrawn from a reduction vessel operating at elevated pressure almost as easily as if the fines were a liquid. The *H-iron* process represents an attractive means of utilizing existing ore fines which have accumulated incidental to preparation of ore for use in blast furnaces. The process is also naturally attractive for an ore which must be finely ground in order to unlock iron values from gangue in a concentrating operation. The pelletizing step required to permit use of such fines in other processes is eliminated.

H-iron in steelmaking.

Bethlehem Steel Co. has incorporated H-iron in both open-hearth and electric furnace heats. Table I summarizes results of open-hearth steelmaking tests using 20.4 pct *H-iron*. Table II summarizes electric furnace heats employing 18 to 32.3 pct *H-iron*. In these ranges, extremely good results were obtained, and furnace men express strong liking for the new material.

In common with all direct reduction processes, the *H-iron* process produces a reduced iron which contains all earthy impurities initially present in the ore. Bethlehem's steelmaking tests were run on *H-iron* made from a high quality Swedish magnetite concentrate, containing only about 1 pct gangue to be slagged off from the steelmaking furnace.

If an ore of low earthy impurity content is available, *H-iron* may be used to replace all scrap normally charged to an open hearth furnace, and it may be used as the total charge to an electric steelmaking furnace. When ores of higher earthy impurity content must be used, local economic conditions will dictate either an increase in the furnace's slag-removal capacity, accompanied by decrease in steel production, or a mixture of *H-iron* with iron from other sources.

H-iron may be produced with a wide degree of reduction—percentage removal of oxygen from ore charged. If *H-iron* is to be melted in an electric furnace, a high degree of reduction will be specified, e.g., 95 pct removal of oxygen. If *H-iron* is to be charged to an open hearth, a lower degree of reduction will be preferred, so that it may be used as a substitute both for purchased scrap and for charge ore.

Use of *H-iron* in the open hearth may be illustrated by an example. Consider an open-hearth shop which has been using the following charge pattern in terms of iron units: 58.0 pct metallic iron from hot metal, 6.4 pct from charge ore, 25.0 pct from home scrap, 10.5 pct from purchased scrap, and 0.06 pct from alloy. To replace ore and purchased scrap with *H-iron*, 6.4 + 10.5 or 16.9 iron units will be required. Of these total iron units 10.5 will be in the form of metallic iron to replace the scrap, and 6.4 units will be in the form of oxides to replace the ore. The degree of reduction of *H-iron* will thus be (10.5/16.9) × 100 or 62 pct.

It will be recognized that the *H-iron* process provides a means not only of up-grading iron ore fines

Table I. Comparison of Basic Open Hearth Heats With and Without H-Iron

	Normal Heat	H-Iron	Under H-Iron
Charging Detail:			
Stone	12,000 lb	12,200 lb	12,000 lb
Wt. Pct of Metallic Charge:			
Ore	7.0	—	—
Scrap	38.0	23.7	28.0
Hot Metal	55.6	55.9	55.4
H-Iron	—	20.4	16.6
Pct Reduction of H-Iron	—	75	63
Buggies	18	13	12.5
Time (Cold)	1:30	0:55	0:40
Time to Hot Metal	2:30	1:25	2:25
Metal & Working Time:			
Flush Time & Amount	0:45–¾ Pot	0:35–¾ Pot	0:35–Full Pot
Time to Lime Boil	4:30	4:25	3:45
Duration of Boil	2:30	1:30	1:45
Time to Melt	7:00	5:55	5:30
Furnace Additions, Lb			
Lime	—	1200	—
Ore	4000	5500	1000
Spar	60	—	200
Hot Metal	—	—	—
Tap Carbon, pct	0.16	0.18	0.17
Charge to Tap Time	8 to 8:30	7:04	6:00
Yield, pct	87.8	90.6	85.6

Table II. Summary of Electric Arc Furnace Double Slag Heats Made Using 93 Pct Reduced H-Iron

Steel Grade	Metallic Charge: Size of Heat, Tons	H-Iron, Pct	Scrap, Pct	Pct Coke Charge	Melt Carbon	Charge to Tap Time	Yield, Pct
4340-AQ	35	32.3	67.7	1.25	0.65	7:20	94.2
1025	35	20.5	79.5	1.0	0.53	5:35	96.3
1025	65	21.6	78.4	0.78	0.39	9:00	95.0
1025	65	18	82	0.7	0.48	7:20	94.5

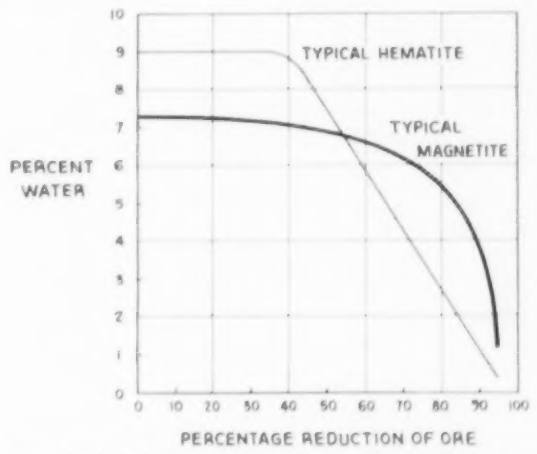


Fig. 6—Typical curves for the conversion of hydrogen to water in the H-iron process.

to an iron melting stock, but also of up-grading fines to a high-quality charge ore. Present methods of pelletizing or sintering iron ore fines to produce lumps suitable for use as charge ore are expensive, both in capital and operating costs. The cost of compacting partially reduced iron powder into *H-iron* chips is small.

Open-hearth charge patterns vary considerably from mill to mill. Whatever the charge pattern, use of *H-iron* as a substitute for purchased scrap and charge ore will result in lower steel ingot cost, not only because of lower unit material costs, but also because of shorter charging time and a better working bath.

Production of necessary hydrogen.

Three new processes have been developed during the past 15 years for the production of reducing gases. During the World War II a number of ammonia plants were constructed using a natural-gas-reforming process:

$$CH_4 + H_2O \rightarrow CO + 3H_2$$

In 1951, Hydrocarbon Research Inc. and Texaco Development Co. offered the *Partial Oxidation* process for licensing. In this process, natural gas, fuel oil, or any gaseous or liquid hydrocarbon fuel is burned with oxygen in a fuel-rich mixture under pressure:

$$CH_4 + \tfrac{1}{2}O_2 \rightarrow CO + 2H_2$$

The third process, developed for duPont by Babcock & Wilcox, uses an atmospheric-pressure, powdered-coal gasifier.

The steelmaker must consider the use of these reducing gas manufacturing processes in a direct iron ore reduction process. Table III gives typical costs of manufacturing hydrogen from heavy fuel oil, natural gas, and bituminous coal.

The incentive to adoption of a direct-reduction process is apparent when these costs are compared with the cost of blast-furnace-grade coke.

Table III. Cost of Manufacturing Hydrogen

	Manufacturing Cost of 1000 Std Cu Ft of H	Cost of 23,000 Std Cu Ft* of H, Required to Reduce One Short Ton of Hematitic Iron
Fuel Oil @ $3.08 per bbl	$0.36	$8.28
Fuel Oil @ $2.10 per bbl	$0.27	$6.21
Natural Gas @ 45c per thousand std cu ft	$0.30	$6.90
Natural Gas @ 20c per thousand std cu ft	$0.17	$3.91
Bituminous Coal @ $7 per ton	$0.25	$5.75

* This quantity of hydrogen allows about a 10 pct purge loss.

Economics of H-iron production.

During the past year, a number of commercial-size *H-iron* installations have been completely engineered. Vendors' quotations were obtained on more than three-quarters of equipment items. The information developed is summarized here in form of two hypothetical plants, one on the East Coast, and one in Texas or a nearby state. Both plants make use of the *Partial Oxidation* process, which is a flexible process, particularly in a steel mill where other uses can be made of oxygen. It should be noted that a *Partial Oxidation* installation may be easily converted from natural gas to fuel oil, so that the cheapest available fuel may be used at all times.

Table IV. Basis of Costs of 2200 Short Tons of Reduced Iron Per Day, Using Partial Oxidation Process to Produce Hydrogen

On the East Coast	Daily Requirement
Fuel Oil for Generating Hydrogen	3260 bbl @ 6,100,000 Btu per bbl
Fuel Oil for Heat	3550 bbl
Total Fuel Oil	6750 bbl = 18.7 MM Btu per Ton Fe
Electricity	330,000 kw-hr
Brackish Water (Once-through)	27,500 gpm
Cooling Tower Make-up Water	780 gpm
City Water	290 gpm
Labor	20 men per shift
Estimated Plant Capital Cost: $24,000,000	
Steam drives used for most compressors	
In Texas	
Natural Gas for Generating Hydrogen	17,500,000 std cu ft @ 960 Btu per std cu ft
Natural Gas for Heat	11,500,000 std cu ft
Natural Gas for Power	4,240,000 std cu ft
Total Natural Gas	33,240,000 std cu ft = 14.5 MM Btu per ton Fe
Electric Power	220,800 kw-hr
Make-up Water for Cooling Tower	2500 gpm
City Water	60 gpm
Labor	20 men per shift
Estimated Plant Capital Cost: $23,000,000	
Gas-engine drives used for most compressors	

Table V. Typical Costs of H-Iron Per Short Ton of Contained Iron in the Reduced State at Two Plants

	East Coast	Texas and Southwest
Fuel Used	Fuel oil @ $3.08 per bbl	Natural gas @ $0.20 per thousand std cu ft
Direct Operating Charges (including maintenance, taxes and insurance at 4.5 pct of capital costs)	$13.32	$6.13
Amortization at 10 pct per annum	3.12	2.99
Profit at 15 pct per annum	4.67	4.48
Increase in value of H-Iron over ore	$21.11	$13.60
Labor taken at $2.75 per man-hr		
Supervision at 25 pct of direct labor		
Electricity at $0.008 per kw-hr		

Table IV shows the basis for costs of 2200 short tons of reduced iron per day on the East Coast and in Texas. The estimate includes all facilities required to receive utilities, that is, all necessary steam generating facilities, water-treaters, electric sub-stations, etc. Grinding facilities are provided to reduce incoming ore from —½ in. to —20 mesh. The Texas plant uses natural gas, and gas-engine drives are specified for most compressors.

Table V summarizes typical costs of *H-iron* per short ton of contained iron in the reduced state for these two plants. With fuel oil at $3.08 per bbl, the manufacturing cost of *H-iron* is $13.32 per ton of elemental iron, above ore cost. With amortization at 10 pct and profit at 15 pct per annum, the increase in value of *H-iron* over ore is $21.11.

The foregoing cost figures are practically independent of the percentage reduction specified. The operating costs per ton of ore charged to the plant decline as percentage reduction declines and more ore is charged, but operating costs per ton of iron reduced to the metallic state remain substantially unchanged.

With natural gas at $0.20 per thousand cu ft, the manufacturing cost of *H-iron* is $6.13 per ton of elemental iron. With amortization at 10 pct and profit at 15 pct per annum, the increase in value of *H-iron* over ore is $13.60.

The attractiveness of an *H-iron* installation in Texas, or other natural-gas-producing region, is apparent from these cost figures.

Method Used During Forced Interruptions In Open Hearth Operations

by George A. Ferris

The Question: "How to shutdown a basic open hearth furnace for both known and varying lengths of time?" is one which operators are unfortunately too frequently called upon to answer.

THE fact that many steelmakers answer this question differently indicates a rather wide divergence of opinion on the subject. Since all can not be right, a coalition of ideas might possibly lead to the one best method.

Questionnaires sent to open-hearth plants.

Questionnaires were sent to 63 open hearth plants in the United States and Canada. Replies were received from 47 plants. Unfortunately, the results left considerable to the judgment of the person preparing the recapitulation, and did not as thoroughly cover such a diversified subject as might have been possible. Much of the detail requested on the questionnaire was ignored, and no attempt was made to group the total number of furnaces employing any particular shutdown method. Methods were, thus, categorized strictly on a shop basis, since it was recognized that each shop would use the method which they liked best, regardless of the number of furnaces involved.

The objective is to minimize hydration and to attempt to maintain a furnace that can be put back into operation in the shortest period of time. Nevertheless, it was evident from the questionnaires, that there was no particular correlation between the methods employed in shutting down and the types of refractories used in furnace construction.

Results of survey show one of four methods with innovations in general use.

The tabulation of the survey indicated that one of four major methods of shutting down an open hearth furnace is generally followed, with some interesting innovations to each method.

Method One: Thirty-three of the 47 plants responding reported a practice of sealing up the furnace empty, with all dampers closed and no firing. Five of these 33 plants reported a practice of maintaining a gas fire up to one week. Two of these plants reported a practice of maintaining a gas fire on the furnaces with weak roofs up to one month. All of these 33 plants reported they would follow this general procedure regardless of the duration of the shutdown.

Innovations to Method One include:

a) Two plants reported a practice of coating the bottoms with tar or pitch as the furnace cools, if the shutdown was for a prolonged period.

b) One plant reported a practice of spreading 2000 lb of coke over the hearth, and one plant reported a practice of spreading burned lime over the hearth.

Method Two: Four of the 47 plants responding reported a practice of sealing up the furnace empty, with all dampers closed and firing with gas to maintain temperatures up to 1500°F. With one exception, these four plants reported they would use this method for an indefinite period of time. The other plant reported they would discontinue the gas fire at the end of two weeks. Two of these four plants reported introducing the gas through the slag pocket bulkheads, while the other two plants introduced the gas over the hearth.

Method Three: Five of the 47 plants responding reported a practice of sealing up the furnace after a partial charge (limestone and scrap) was added. Two of these 5 plants reported a practice of maintaining a gas fire up to two weeks, and one of the five plants reported they would leave the furnace empty, if the duration of the shutdown was going to be more than one week. One of these five plants reported a practice of charging the furnace with limestone and scrap and melting the scrap down level before shutting fuel off. This particular plant reports holding furnaces in this manner up to one year without difficulty.

Method Four: Five of the 47 plants responding reported a practice of sealing up the furnace after a wet charge was added (scrap-limestone-ore-hot metal), and firing with gas for periods up to one month. One of these five plants reported that with this practice they fire the furnace until after the slag flush, then cut off the fuel and seal the furnace. All five plants reported they would use this method for periods between one week and a month. For known periods of longer duration they would leave the furnace empty.

Some shutdown methods adapt themselves more readily to flexibility.

Frequently, periods of shutdown are not too firmly fixed, and some of the shutdown methods described adapt themselves to flexibility more readily than others.

At Ford's open hearth plant, the wet soaker is preferred, with the furnace sealed up and kept warm with a gas fire. Such a practice would be employed for periods up to one month. Experience of sealing up the empty furnace and keeping warm with gas for a period of two weeks resulted in decomposition of the bottom; this was attributed to the moisture content of the gas. The use of dehumidifiers and better methods of sealing are worth considering.

GEORGE A. FERRIS is with the Steel Div., Ford Motor Co., Dearborn, Mich. This survey is to be presented at the AIME National Open Hearth Conference, Pittsburgh, April, 1957.

Ironmaking In the USSR

by E. W. Voice and S. Klemantaski

Recent exchange visits between Soviet and Western European engineers have been richly productive of information on the Russian iron and steel industry. Sponsored by the United Nations' Economic Commission for Europe, experts have visited works in the Ukraine, Caucasus, and Ural areas. The views herein are drawn from personal impressions, recent technical literature, and the reports of two teams of British experts that visited the USSR in 1955 and 1956.

SOVIET iron and steel production is largely concentrated in two areas: a) at the South, mainly in the Ukraine, where 16.6 million tons of pig iron were produced in 1955, and b) the Urals, which produced 11 million tons. The outstanding feature of future development of the Soviet steel industry is the projected growth of production in the Siberian region during the next 10 to 15 years. Since there is little scrap in Siberia, there will have to be a very large increase in pig iron production.

Soviet Union well provided with ore, coking coal, flux, and water.

Data on ore reserves are unreliable, since many regions, especially those away from railways, have not been prospected thoroughly. Prospecting is being vigorously pursued, and in 1955, ore production was 71.9 million tons.

In the past, the ores had a fairly high iron content, but these high grade deposits represent less than 20 pct of total ore reserves, and soon ore with only 17 pct iron will be mined. Unlike some British lean ores, this can be concentrated, and it is proposed to raise the iron content to about 40 pct before smelting.

The reserves of manganese ores are considered to be virtually unlimited.

E. W. VOICE and S. KLEMANTASKI are with the Ironmaking Div. of the British Iron and Steel Research Assn. (BISRA). This paper is to be presented at the AIME Blast Furnace, Coke Oven, and Raw Materials Conference, Pittsburgh, April 1957.

In spite of extensive coal washing, coke used in the South is rather high in ash content, and it is partly because of this that beneficiation and sintering of iron ores is carried out so extensively.

Water supplies in the USSR are adequate for blast-furnace requirements, and the great rivers of Siberia are being looked upon as potential power sources for electric blast furnaces.

Ural steel industry developed for strategic reasons.

The Southern ironmaking district has developed *naturally*, i.e., it is reasonably close to sources of raw materials and is easily accessible to a large steel market. Development of the Ural region, however, has been artificial. Fuel for smelting local high grade ores used to be charcoal, derived from abundant local timber, and the exhaustion of this fuel led to a relative decline in the importance of the Urals as an ironmaking district. The revival of this region, which started in the late twenties, was a deliberate act of government policy, the strategic justification for which was demonstrated in World War II when the Southern industry was largely destroyed. The Ural iron-making industry received a tremendous impetus during the war (ten blast furnaces were brought into operation), and many skilled Ukrainian blast-furnace operators and technicians were transferred. Coking coal was originally supplied to the Ural region by rail from Kuzbas, 1250 miles away. Ural ore was sent in return, this arrangement being known as the Magnitogorsk-Kuznetsk Combine. Later, good quality coal was obtained from Karaganda, considerably closer.

Fig. 1—Steel plants and resources of the southern region. Map courtesy of the British Iron and Steel Federation.

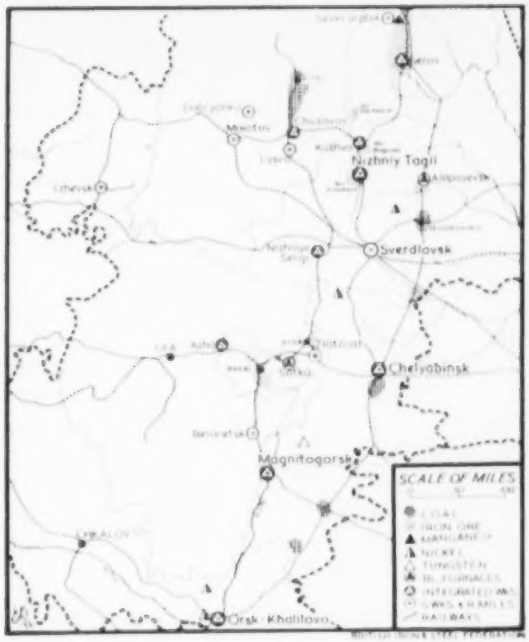


Fig. 2—Steel plants and resources of the Ural region. Map courtesy of the British Iron and Steel Federation.

Markets for Ural iron and steel production were provided, again artificially, by building heavy industrial enterprises.

In Siberia, new large works to be built.

A similar artificial development is planned for Siberia. A completely new integrated works, which will be one of the largest in the Soviet Union, is to be built in Western Siberia during the 6th Five-Year Plan (1955-1960) to supply a simultaneously growing market with tubes and light and medium sections. Building of the new Eastern Siberian works to specialize in sheets and sections will also be started.

Both for general efficiency and because manpower difficulties are likely to be encountered, the new Siberian works are to be provided with the latest highly automated equipment. It is here that 2000 cu m blast furnaces and 200 sq m sintering strands are to be built. Supplementary ironmaking capacity is to be established in the form of electric blast furnaces.

Iron & Steel Ministry exercises substantial control over industry.

The organization of this Ministry, which is situated in Moscow, is partly geographical and partly functional. Thus, there are three sections for dealing with the Central, Southern, and Eastern regions of the industry, and two all-Union sections, one being for special steels and the other for engineering, i.e., plant design. The Ministry supervises the course of research, the dissemination of technical information, the organization of conferences, etc.

The overall production plans are worked out annually by the Ministry on the basis of estimates drawn up by the governmental Central Planning Commission in order to coincide with the targets set by the government every five years. All iron and steel requirements are sent to the Ministry, which allocates the total production between the various regions, giving them considerable latitude in detailed planning.

Supplies of raw materials are allocated to works sufficient for the planned production. If failures of raw material producers to fulfill these allocations are encountered, adjustments are made, locally if possible, otherwise by reference to the Ministry.

The appointment of the highest executives of the industry is in the hands of the Ministry, as is the planning and authorization of development work in the 25 to 130 million rouble range. Below this, authorization is obtained from regional organizations, but the works director can authorize expenditure up to 3 million roubles.

Blast furnace design tends toward larger furnaces.

The total number of furnaces in the USSR is about 130, the present tendency being to concentrate pig iron production in larger blast furnaces. In 1940 some 28 pct of the pig iron was produced in furnaces larger than 1100 cu m, and by 1955 this had increased to 53 pct. This large blast furnace policy was not started until comparatively recently, and its adoption, against considerable criticism, was facilitated by successful American practice with blast furnaces having capacities of some 50,000 cu ft.

Useful volume, i.e., from the lowest level reached by the big bell to the iron notch, is how the size of furnaces is judged in the Soviet Union. This system has the advantage over the hearth-diameter system of being additive— n furnaces of useful volume, V, each are equivalent for calculation purposed to one with a useful volume of nV. The parameter of productivity is the *coefficient of utilization of useful volume*, which is simply the useful volume in cu m divided by the daily output of ordinary pig iron.

There is considerable variation in the coefficient from works to works (and even within a works)

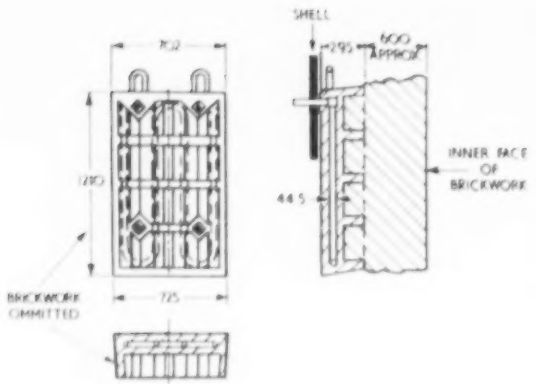


Fig. 3—(Above) Design of the vertical stack coolers in the lower 33 ft of the stack on No. 10 furnace at the Dzerzhynski Works. Dimensions in mm.

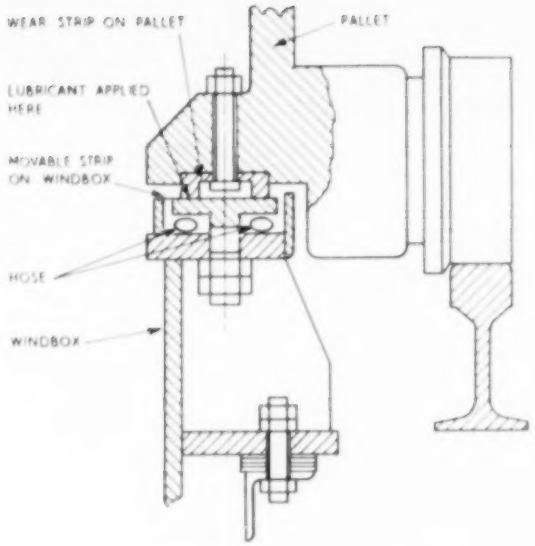


Fig. 4—(Right) Design of the windbox seal used on USSR sintering machines.

and some of the known individual coefficients have been included in Table I, which also shows the corresponding operating data.

The next stage in the growth of Soviet blast furnaces is the 1513 cu m (53,400 cu ft) furnace. At least one of these has either started or is just about to start operating. One is being built at Magnitogorsk, and some are to be built in Siberia. There also has been discussion about a 1700 cu m (60,000 cu ft) furnace.

Considerable interest has been aroused by the plan to build furnaces of 2000 cu m (70,600 cu ft) capacity. It is not so much the actual size of the furnace—after all there is an 1810 cu m (63,900 cu ft) furnace in the U. S.—as the high pig iron output which is anticipated. This was expected to be 5000 metric tons (5511 short tons) a day at a coke:iron ratio of 0.6, which implies a coefficient of utilization of 0.4, far better than any yet obtained. This poses many problems in the supply of raw materials and the disposal of iron and slag. For comparison, the best coefficient so far, 0.59, has been obtained at Magnitogorsk Nos. 6 and 8. The remarkable coefficient of 0.4 is hoped to be attained by such revolutionary measures as the use of iron coke and a blast containing carbon dioxide. The need for two tapholes for dealing with the high production rates of iron and the difficulties of maintaining satisfactory charge permeability in such a large furnace have been pointed out. Informed Soviet opinion now seems to be that output from the 2000 cu m furnace will be initially 3400 tons (3748 short tons) per day. Table II shows the dimensions of this and other furnaces.

Blast furnace operation features high top pressure, high blast temperature, high sinter (ordinary and self fluxing) burden, and emphasis on constancy of operating conditions.

High top pressure was first adopted in the USSR in 1940, but only after 1950 was its use extended rapidly. At the end of 1955, 60 pct of total iron production was from furnaces using this method. A 6 to 10 pct increase in productivity has been obtained, but coke rates have not been affected so much. The highest top pressure so far used is about 14 psig for short periods, but the maximum for normal operation being about 11½ psig. It is proposed to run furnaces at about 21 psig. Dust loss, which was a troublesome feature of much Soviet practice, is radically reduced. This should simplify the utilization of the energy of the top gas, a problem to which some attention has been given.

The importance of charging methods for getting the best out of high top pressure is appreciated. Some authorities consider that it is only with fully prepared burdens that optimum results are achieved, and that the old idea of using high top pressure to avoid having to prepare the burden is erroneous. It has also been found that better refractories are required if the campaign life of furnaces operated with high top pressure is to be increased.

Blast humidification, automatically to a constant value (of the order of 2.5 pct by volume), is almost universal in the USSR—recently it was stated that 90 pct of the total pig iron was produced using humidified blast. There is still discussion as to whether it is the constancy of moisture content or the beneficial action of the moisture as such that contributes the claimed advantages of the practice, but most experts seem to think that the latter is the major factor. The transition to blast with a constant moisture content of 2.5 pct by volume leads, on the average, to production increases of 7 pct and coke-rate decreases of 2 pct.[1]

An objection made to blast humidification was that it might lead to hydrogen pickup by the iron, giving steel with inferior properties, but this has been disproved. Nor have any deleterious effects on the size of the combustion zone at the tuyeres been observed.

The extent to which blast can be humidified without having to increase coke rate depends on the blast temperature that can be produced. Coupled with the extensive use of this practice, it is only natural that keen attention should have been given to the provision of adequate stove capacity. At Magnitogorsk, for example, 1.1 to 1.2 million sq ft of total stove heating surface are provided per furnace. Temperatures as high as 900°C are obtained, and alloy steel blowpipes are used. In the plans for the 2000 cu m furnace, blast temperatures of 1200°C

Table I. Performance of Some Soviet Blast Furnaces

Plant	Hearth Diam	Volume Cu M	Coefficient	Coke: Iron Ratio	Slag: Iron Ratio	Iron Make, Tons	Sinter, Pct
Zaporozhstal'	7 m	1000	0.83	0.86	0.8	1200	80
	8	1300	0.83	0.86	0.8	1580	80
	8	1300	0.83	0.86	0.8	1580	80
	8	1350	0.79	0.86	0.8	1720	80
Rustavi	6	720	0.86	0.90	0.6–0.7	850	60–70
Magnitogorsk	8	1381	0.61	0.66	0.48	2250	86
	8	1381	0.59	0.63	0.48	2350	100
Novo Tagil'	8.2	1386	0.69	0.67	0.65	1984	65–70

Table II. Dimensions of Large Soviet Blast Furnaces

	Soviet Furnaces			American Furnace*
Working Volume, cu m	1386	1513	2000	1810
Working Volume, cu ft	48,950	53,400	70,600	63,900
Diameters, ft:				
Bell	15.09	15.74	17.7	16.5
Throat	21.3	21.6	24.27	23.0
Bosh	30.5	31.5	35.75	33.3
Hearth	26.9	28.2	32.5	30.4
Useful Height, ft	89.5	91.8	94.1	—

* A Great Lakes furnace, quoted in Russian literature.

Table III. Magnitogorsk Practice, Change in Operation of Blast Furnaces A and B at Various Periods of Self-fluxing Sinter Charge

Period	Jan.–Nov. 1952		June–Nov. 1953		April–June 1954		Visit June 1956
Furnace	A	B	A	B	A	B	
Composition of charge, pct							
Iron ore	25.1	16.5	6.4	4.95	15.1	12.6	—
Oxidized sinter	22.6	27.8					
Self-fluxing sinter	29.8	32.1	78.1	81.0	77.5	80.0	100
Manganese ore	3.4	4.1	4.5	3.5		0.95	—
Limestone	13.6	14.2	9.2	8.55	4.8	5.25	—
O.H. slag	3.6	3.3			1.85		—
Metal additions	1.9	2.0	1.8	2.0	0.75	1.2	0.45
Consumption—lb per 1000 lb pig iron							
Self-fluxing sinter	629	647	1528	1536	1482	1506	1760
Iron ore components	1612	1533	1653	1631	1770	1745	1760
Limestone	283	288	180	163	91	99	—
Coke (dry)	786	742	707	702	681	665	630
Slag vol, lb per 1000 lb pig	591	614	543	538	510	514	480
Dust trapped, lb per 1000 lb pig	34.2	25.5	24.8	23.3	22.5	22.1	55
Furnace productivity, pct	100	100	110	106	113	116	—
Top-gas production, cu m per metric ton coke	3951	3975	3536	3547	3490	3440	
Top gas, Pct CO	29.40	28.65	28.23	27.88	27.60	27.28	25.8
Blast temperature, °C	771	790	749	785	809	812	800–900
Top-gas temperature, °C	319	349	365	380	399	416	370
Blast pressure, atm gauge	1.33	1.83	1.74	1.73	1.66	1.82	2.35
Top pressure, atm gauge	14	66	59	70	56	73	0.8–1.0
Iron composition, pct, Si	68	67	71	80	83	66	0.7
Mn	1.39	1.62	1.35	1.15	0.40	0.54	0.2
S	046	045	041	040	040	037	0.03
P	133	138	104	102	133	117	0.11
Slag composition, pct, SiO_2	37.25	37.43	37.50	37.32	38.76	37.11	36
Al_2O_3	15.32	15.52	15.76	15.52	15.90	15.67	
CaO	39.79	39.56	37.85	38.26	39.80	39.85	39.75
Other oxides and S	8.26	8.50	9.66	9.14	8.31	7.99	7.6
Sinter Basicity CaO/SiO_2		0.78		0.86		1.25	—
Sinter Reducibility		36.9		40.8		42.9	—

are contemplated, together with humidification to 50 g per cu m.

The average proportion of sinter in the furnace burden has shown great increases: 20 pct in 1940 and 54 pct in 1955. By 1960 the annual sinter production will be 73 million tons, and its proportion is expected to increase to over 80 pct, all of this being self fluxing. The idea is that eventually the furnace charge will consist of two components only, coke and fluxed sinter. There is some doubt, however, as to the suitability of this practice for furnaces in the southern region where the combination of relatively high-silica ores and high-sulfur cokes may require the separate charging of some flux. Such considerations underline the importance of getting fluxed sinter of sufficiently high basicity and yet without deleterious effect on furnace operation, and this has been investigated at the Magnitogorsk Metallurgical Combine in full-scale trials. The data obtained is shown in Table III, and information derived from the furnace books and instruments when the U.K. delegation visited this plant is given in the last column of the table.[1]

At one works, where fluxed sinter of basicity 1.25 is charged hot, iron production increased by about 12 pct and fuel consumption decreased by about 11 pct, compared to production with unfluxed sinter. With a fluxed sinter basicity of only 0.6 the corresponding figures were 3 to 5 pct and 4 to 6.5 pct.

Five central sintering plants, each with a capacity of ten million tons of ore, are to be completed within the next few years. This will inevitably mean that a smaller proportion of sinter will be charged hot.

A factor to which great importance is attached in Soviet blast-furnace practice is constancy of operation. The humidification of the blast has already been mentioned in this connection, and the relative constancy of the charge when using sinter is credited with some of the advantages of sinter operation. The attainment of constant conditions is also a major aim of the drive to automate the furnaces, since this will eliminate the human-factor disturbances which often occur, e.g., when shifts are changed. The plans for automatic control are ambitious; their realization will require extensive development of instrumentation, plant design, and knowledge of the blast-furnace process.

Modern blast furnaces of orthodox American-type design.

The majority of modern Soviet furnaces are, what may be termed, orthodox American in design. Lines were standardized in the thirties and these have been adhered to fairly closely.

Table IV Comparison of Operating Results for Furnaces with Vertical and Horizontal Coolers for Trial Month (Nov. 1955) at Dzerzhynski

Furnace No.	10	9
Coolers	Vertical	Horizontal
Slag-iron ratio	0.73	0.69
Sinter-iron ratio	1.53	1.63
Time off, hr	6.3	13.2
Daily pig iron output, tons	1880	1734
Pct Si in iron	0.75	0.67
Coke-iron ratio	0.85	0.86
Number of slips (checks)	8	30

Table V Properties of Soviet Blast-Furnace Coke

	Ash Content, Pct		Sulfur, Pct		Mechanical Strength (Remainder in Drum) Kg		Moisture Content, Pct	
	South	East & Center	South	East & Center	South	East & Center	South	East & Center
1940	10.2	12.6	1.7	0.6	330	290	5.0	4.7
1950	10.1	11.2	1.8	0.5	340	320	3.2	3.9
1954	9.6	10.9	1.8	0.5	350	320	—	2.8
1955 (first half of year)	9.5	11.0	1.8	0.5	350	320	2.9	2.8

The official stack life of a furnace is four years, after which repairs are carried out under the auspices of the Ministry of Iron and Steel. It is often necessary to carry out major repairs locally in between official repairs. Carbon hearth walls, protected initially with fireclay, are used up to the tuyeres, the rest being high-alumina bricks. Numerous couples are built into the lining and also in the various off-takes. Their indicated temperatures are used as a check on the distribution of gases in the stack. Ultrasonic rods have also been tried out for detecting lining wear.

There is interest in designs of stack cooling, and recently a trial period extending for ten years was concluded in which vertical coolers in the stack were used in place of horizontal ones. The latest phase of this work was a comparative trial of two 27-ft hearth diam furnaces, one with normal horizontal coolers and the other with the stack coolers in the lower 33 ft of the stack. The furnace was blown in at the end of 1953, and the lines were measured in April and November 1954 and January 1955. The furnaces were blown out and emptied for the examinations. In the last measurement it was found that the lower coolers were exposed, but no deterioration in operation had been experienced either then or during the following year. Table IV shows the operating results for the furnace compared with those of a furnace identical in lines but with horizontal coolers.

Beneficiation aims at burden with a minimum 45 pct Fe.

The importance of beneficiation is fully appreciated in the USSR and many large plants have already been built as part of a plan still in development. The aim in general is that the iron content of the blast-furnace burden should be at least 45 pct, but often far higher iron contents are achieved. For example, at one plant on the Krivoi Rog (Ukraine) ore field, magnetite with an iron content of 35-40 pct is concentrated to give a product with 57 to 65 pct Fe. The ore is crushed in four stages to 200-mesh, passed through wet magnetic separators and dewatered in Dorr-type, internal-discharge vacuum filters.

Sinter plants are of the Dwight-Lloyd type and are of standardized designs. Instrumentation and control are often not as good as on the blast furnace. Typical operating data obtained at a Ural plant are given below:

Strand speed: 2.5 m per min
Bed height: 250 mm
Time to sinter: 10 min
Windlegs: 13
Peak windleg temperature: No. 12 or 13 at 350° to 400°C
Fan rating: 3500 cu m at 1100 mm H_2O, 130°C
Fan power: 1300 kw, 1500 rev
Feeder tables: normal gate and plough types.
Sinter cooling: none, charged hot to furnaces.
Coke in raw mix: 3.8 to 4 pct
Circulating load: 30 pct
Output to blast furnace: 1700 tons per day.
Broken sinter: 1.6 tons per cu m

The final sinter screen is set at 25 mm, and the self-fluxing sinter contains 55 pct Fe and 0.04 pct S. Plant is shut down for one day per month for routine maintenance and for a ten-day major overhaul every three years.

An interesting design of pallet seal, shown in Fig. 4, is used at some works in the USSR. The full weight of the pallet is taken by the rail. A grease seal is provided between the pallet and a special plate along the length of the windbox. This special plate is spring loaded on to the pallet by means of two water-filled hosepipes of $1\frac{1}{2}$-in. external diam. It is claimed that this is very satisfactory, and that all sinter machines at Magnitogorsk will be so modified during the next periods of major overhaul.

The special problems of the production of self-fluxing sinter are attracting considerable attention. It has been found, for example, that the grinding of the limestone has a considerable influence on the sintering process, the size recommended being < 3 mm. It is claimed that good sulfur removal (> 90 pct) is still possible, even with added limestone.

Coke production doubled since 1940.

Since 1940 the annual production of coke in the USSR has approximately doubled, the Donbas and Kuzbas remaining the major sources of coking coal (about 60 and 30 pct, respectively). In spite of delays in the completion of coal preparation plants, the quality of Soviet blast-furnace coke has, on the whole, improved since 1940. This is shown in Table V.

Not as much attention to blast-furnace coke properties has been given in the USSR as in America, but the amount of work on coke is likely to increase as the proportion of high capacity furnaces in the USSR rises.

Soviet ironmaking industry compares well with that of other countries.

The Soviet steel industry has been specially favored in the national economy for many years, and it has undoubtedly reached a high level of efficiency. The ironmaking section is one of the most advanced, and their best practice compares well with that of any other country. Though in its early days foreign influences played a considerable part, the Soviet ironmaking industry is now rapidly developing its own special character, and is perfectly confident of its ability to raise productivity and efficiency even higher. The authors consider this confidence is fully justified.

Editor's References:

1 USSR: Constant Humidity Blast Furnaces, JOURNAL OF METALS, p. 1139, Sept. 1956.
2 Self Fluxing Agglomerates in the USSR, JOURNAL OF METALS, p. 852, July 1956.

Hydrogen In Steelmaking Practice

Based on a rapid analytical procedure for hydrogen and a reliable sampling method for obtaining specimens from a molten steel bath, a series of three acid open hearth, two basic open hearth, and seven basic electric furnace heats were examined through the refining period, at tap, and in some instances during pouring for variations in hydrogen content. Experiments and calculations are presented to show that the measured hydrogen content is the result of two competing processes, one of which drives hydrogen into the metal from the gas and slag phases and the other eliminating hydrogen through the CO boil. Hydrogen absorption rates are calculated to show the differences which exist among the acid and basic open hearth processes and the basic electric process.

by Henry Epstein, John Chipman, and Nicholas J. Grant

FOR many years steel producers have been concerned with the presence of hydrogen in steel. Hydrogen dissolved in excess of its solid solubility at the melting point may cause bleeding and gross unsoundness in ingots and castings. In fully-killed steels the hydrogen content which results in these difficulties varies with the alloy content[1] and may range from 6 to 12 ppm.* It is also recognized that a smaller content of hydrogen, as low as 1 or 2 ppm, plays a part in causing other defects such as flakes,[2,3] hairline cracks,[4] and generally lowered ductility.[5]

* 1 ppm = 0.0001 wt pct = 1.11 cu cm per 100 g = 0.0873 R.V. (volumes of H_2 per volume of metal).

The deleterious effects of small amounts of hydrogen pose a special problem in forging grade steels where maximum mechanical properties are desired. The forging manufacturers have long incorporated subcritical annealing periods in heat treatment cycles to remove hydrogen. This is made possible by the relatively high rate of diffusion of hydrogen in ferritic steel. Corrective heat treatment is not very practical for austenitic grades because of the relatively low rate of diffusion of hydrogen in austenite. However, even in ferritic grades, the effectiveness of heat treatment diminishes rapidly as the size of the part to be treated increases. The time required to remove a specified fraction of the hydrogen present increases as the square of the diameter of the section, making the treatment of large sizes impractical.

In order to prevent bleeding and gross unsoundness due to hydrogen, and in view of the inadequacy of corrective heat treatment alone to provide optimum properties when hydrogen is present in large sections, efforts to limit the hydrogen content must be taken while the steel is still liquid. The main subject of this paper is a discussion of the factors affecting the hydrogen content of liquid steel in acid and basic open hearth, and basic electric two-slag furnace processing.

Literature Survey

Because many of the results and observations reported in the literature have a direct bearing on the results obtained in the present research and form part of the basis for conclusions reached, a brief summary of the findings is necessary.

Methods for experimental investigation of hydrogen in liquid steel are comparatively new. The first attempts to estimate the hydrogen content of the open hearth bath were by Kalling and Rudberg,[6] who devised a method for collecting gases evolved from the boiling bath of a basic open hearth furnace. They found that the gas during the boil generally contained 2 to 3 pct H_2. From this and Sieverts'

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solubility data they indicated that the bath contained about 3.5 to 4.5 ppm H. The method of gas collection was improved by von Hofsten, Kalling, Johansson, and Knos, and they concluded that the method gave a more valid figure for hydrogen than they could obtain by sampling and analysis of the liquid bath.

Chiuko reported similar studies.[9,10] The hydrogen content of the bath was found to decrease during the oxidizing period of the heat at a rate directly proportional to the rate of carbon elimination. Minimum carbon oxidation rates of 0.3 pct C per hr were recommended to obtain low hydrogen steels, in agreement with the observations of von Hofsten et al. Pronounced deviations in the observed rates of hydrogen elimination from a theoretical calculation of the effect of the boil were ascribed to simultaneous hydrogen absorption from the furnace atmosphere. Water vapor in the furnace atmosphere was considered the source of hydrogen, and the effect of various fuels and the moisture content of slag additions, such as burnt lime, on the moisture content of the furnace atmosphere was noted. A detailed theory of the absorption of hydrogen in electric furnace practice was formulated. This theory emphasized the importance of the high temperature at the arcs on absorption of hydrogen as well as of nitrogen.

Sims, Moore, and Williams[11] reported the results of an extensive study in 1948. They used hot extraction analyses performed on metal samples taken in a split copper mold to follow the hydrogen content during the heat. The effectiveness of the boil in removing hydrogen was again found to vary with the type of practice, being more effective in acid than in basic practice, and more effective in electric than in open hearth practice. Initially high hydrogen content associated with rusty or oily scrap charges did not result in high values at tap provided a vigorous boil had taken place. In fact, the attainment of a vigorous boil was considered the prime factor in obtaining consistently low hydrogen content at tap. Next in importance was the careful drying of ladles, runners, and molds to prevent excessive hydrogen pickup during tapping and teeming.

Wentrup, Fucke, and Reif[12] in 1949 reported hydrogen analyses of metal samples taken in a quartz pipette and analyzed by the method of Bennek and Klotzbach[13] (hot extraction at 600° followed by vacuum tin fusion at 1150°C). Their results confirmed the previously reported difference in the hydrogen content of acid and basic open hearth steels. A minimum rate of carbon oxidation of 0.3 pct per hr for acid open hearth and 0.5 pct C per hr for basic open hearth steels was recommended to maintain low hydrogen content.

Piper, Hagedorn, and Backes[14] published results of extensive tests using an improved design of the quartz suction tube described by Wentrup et al. They concurred to a large degree with the conclusions reached by Wentrup although obtaining substantially lower actual hydrogen contents. Along with the effect of the type of slag, they noted an inverse relation between the hydrogen content of the bath and the ferric iron content of the slag.

Barraclough[15] reported results of hydrogen analyses on samples taken in a notched-pencil mold constructed of copper. Special attention was paid to two-slag basic electric practice in which the hydrogen content was found to increase when the reducing slag was added. This increase was associated with the moisture content of the burnt lime and was reduced to a minimum by thorough drying of the additions. Similar findings were reported by Piper et al.

Table I. Effect of Mold Condition on Hydrogen Content of Killed Steel

Casting No.	Description*	Hydrogen Content, Ppm
1	Clean steel mold, 6 in. diam, 10 in. depth	4.9
2	Heavily tarred steel mold, 6 in. diam, 15 in. depth	8.6
3	Clean steel mold, 6 in. diam, 10 in. depth	4.1
4	Dry sand mold, 10 x 15 x 12 in.	4.1
5	Green sand mold, 10 x 15 x 12 in.	4.6

* All molds were poured from the same ladle.

Hydrogen Sampling and Analytical Apparatus Used

The great mobility of hydrogen in liquid steel and in solid ferritic steel makes the use of special sampling techniques necessary in order to retain all the hydrogen. Two main types of approach to the problem of retaining the hydrogen have been employed in previous work: 1) the sample was taken in a device providing for the collection of escaping hydrogen,[16,17] or 2) the sample was drastically quenched and maintained at very low temperature to prevent the escape of any hydrogen.[1,2,18]

The devices used in this work have been of the second type. The final design adopted was the modified Taylor sampler shown in Fig. 1. It consisted of a heavy-walled copper cylinder with a tapered hole to which a rubber bulb was attached by iron piping. A hardened steel punch was provided for rapid ejection of the sample from the copper sampler. A plug consisting of a small roll of copper gauze was inserted in the hole to regulate the sample length.

Fig. 1—Modified Taylor sampler for hydrogen.

The sampling procedure used is outlined below:

1) A well-slagged spoon of liquid metal was withdrawn from the furnace, the surface wiped free of slag, and the metal killed with 0.1 to 0.2 pct aluminum wire (time required—5 to 15 sec).

2) The tip of the copper sampler was momentarily immersed in the liquid metal and a sample

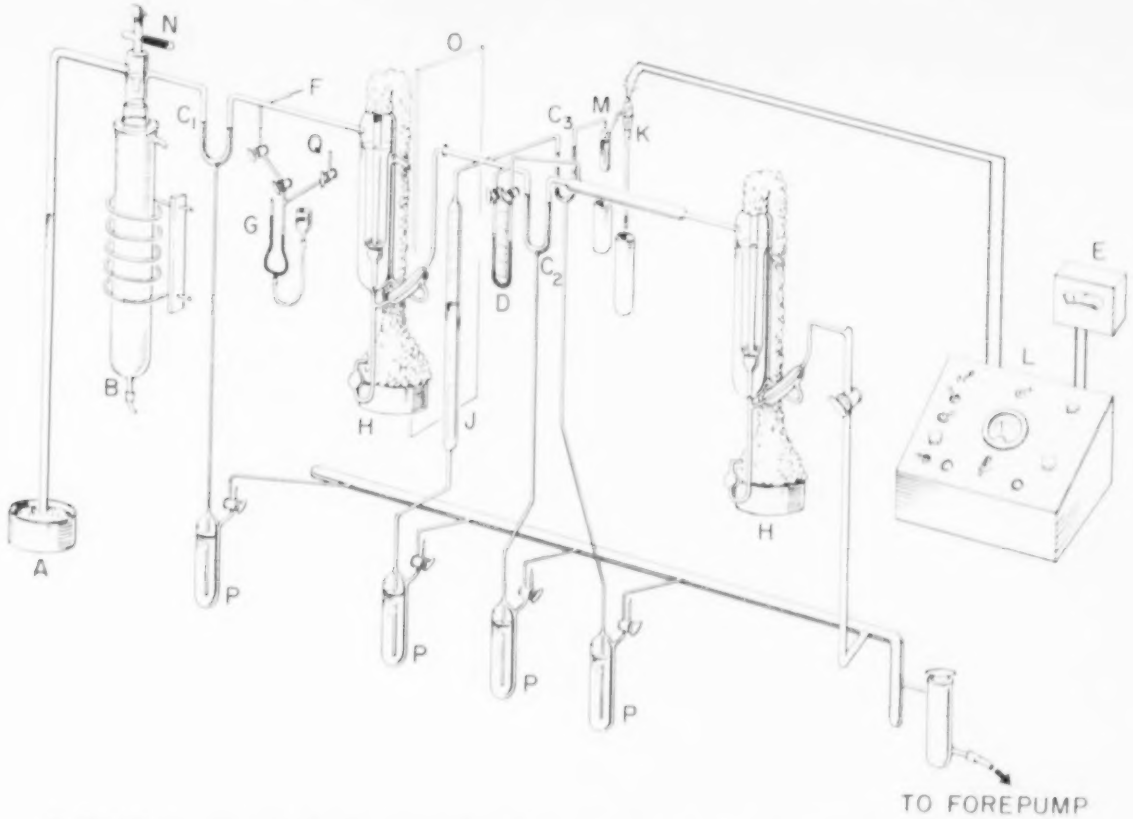

Fig. 2—Analytical apparatus for hydrogen determination in steel. *A*, mercury lift, for sample introduction; *B*, induction furnace assembly, containing tin bath; C_1, C_2, and C_3, mercury valves; *D*, butyl phthalate manometer; *E*, ammeter; *F*, palladium tube, for introducing hydrogen for calibration; *G*, mercury manometer, for introducing gases for calibration; *H*, mercury diffusion pumps; *J*, variable volume burette; *K*, thermal conductivity cell, surrounded by ice-water bath; *L*, Wheatstone bridge; *M*, mercury trap, surrounded by dry-ice and acetone bath; *N*, magnetic slide, to prevent condensation on prism; *O*, asbestos sheet insulation; *P*, mercury reservoirs; and *Q*, known volume, for calibration purposes.

sucked into the tube by means of the rubber bulb. The sample was then immediately ejected into cold water by placing the sampler on a stand and striking the punch (maximum time required—10 sec).

3) The sample was agitated in cold water for about 10 sec and placed in a bottle of liquid nitrogen for storage until analysis.

This device combined the suction feature introduced in German designs, preventing exposure of the metal to the atmosphere as occurs on pouring, with the rapid quench obtained in a copper mold as utilized in several British and American designs. The entire sampling operation took less than 30 sec. The copper tubes were used over and over again, needing only occasional pickling and reaming to maintain a smooth bore.

A sampler marketed for taking spectrographic pin samples was also used in some instances. This device was extremely simple, consisting merely of an evacuated glass tube about 4 in. long. The tips of the glass tube were drawn down so that when one end was immersed in a spoon of liquid metal, the tip melted away and the tube filled up with metal. Samples taken with this device were handled in the same fashion as those taken with the Taylor sampler.

The most successful methods of extracting hydrogen from steel samples for analytical purposes have been the hot extraction method[9, 10] and the tin fusion method.[10, 11, 12] The hot extraction method involves heating the sample in a vacuum to temperatures ranging from 300° to 800°C, causing the hydrogen to diffuse out of the solid sample. In the tin fusion method, the sample is dissolved in liquid tin in a vacuum furnace at a temperature of about 1100°C, and the hydrogen is pumped out of the melt. Various methods of collecting and analyzing the extracted gases have been successfully employed.

The analytical apparatus used in this work incorporated the vacuum tin fusion extraction furnace described by Carney, Chipman, and Grant.[10] The analysis of the extracted gases for hydrogen was based on the thermal conductivity method described by Shields, Chipman, and Grant.[11] The following describes certain improvements that have been made.

A sketch of the apparatus is shown in Fig. 2. The sample was introduced into the vacuum system through a mercury lift (*A*) and held for a period of about 1½ min with all mercury cutoffs (C_1, C_2, C_3) open to allow any air and solvent introduced with the sample to be pumped off. The collecting system was then closed by raising the mercury cutoff (C_2) and introducing the sample into the furnace (*B*) containing the tin bath. Manipulation of the sample was accomplished by a magnet (nonmag-

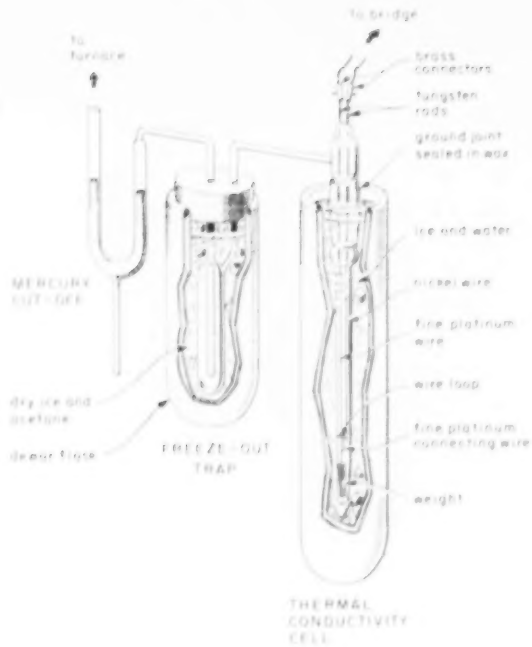

Fig. 3—Detail of thermal conductivity cell and freeze out trap

netic samples were handled in a magnetic cup). The tin bath contained about 1.0 pct Si and 0.5 pct Al to suppress CO evolution, and was maintained at a temperature of about 1100°C. As the sample dissolved, the hydrogen plus a small amount of N_2 and CO was liberated, and these gases were pumped into the analytical section of the apparatus by a mercury diffusion pump (*H*). A period of 5 to 15 min was required to collect the gas from samples weighing 1 to 10 g. At the end of the collection period the furnace was isolated from the analytical section by raising the mercury cutoff (*C*). The pressure in the analytical section was then adjusted by means of the variable volume burette (*J*) into the range 1.4 to 1.6 mm Hg as determined from the butyl phthalate manometer (*D*). A reading was taken on the ammeter (*E*) in the thermal conductivity gage Wheatstone bridge circuit (*K*, *L*) described by Shields et al.[11] This completed the operations necessary for an analysis. The equipment was made ready for another analysis by evacuating the previous gas sample and then opening the mercury cutoffs *C*, and *C'*.

The quantity of hydrogen collected was calculated from the partial pressure of hydrogen (determined from the ammeter reading in the thermal conductivity gage circuit as previously calibrated), the total volume of collected gases (determined from the burette reading), and the temperature of the collected gases (read from a thermometer). From this total quantity of hydrogen a *blank* correction was subtracted equal to the amount of hydrogen collected in the absence of any sample. This corrected quantity of hydrogen was divided by the sample weight to give the hydrogen content.

The constant pressure method used was preferred to the more usual constant volume approach, because in the range of total pressure from 1.4 to 1.6 mm Hg and over 50 pct H, in the gas, the ammeter reading was found to be directly proportional to the partial pressure of hydrogen and independent of the exact amount of CO or N_2 present. This independence of the reading with total pressure allowed the use of the relatively insensitive butyl phthalate manometer. A detailed drawing of the thermal conductivity gage used to obtain the readings is shown in Fig. 3.

Excellent operation of the equipment was obtained if rigorous attention was given to several important details. These included thorough *bake out* of the equipment before starting any analyses, careful temperature control of the tin bath, frequent *blank* checks, and careful use of the thermal conductivity gage cell. Of equal importance was the need for careful sample preparation, since a clean sample surface was essential in obtaining consistent results. Prior to analysis the samples were temporarily taken out of the liquid nitrogen storage vessel and metal-shot-blasted to remove scale and rust. This operation took less than 30 sec. At the time of analysis the shot-blasted sample was removed from the liquid nitrogen and a piece of appropriate size broken off by holding the sample in a vise and hitting it with a hammer. This piece was allowed to warm up to room temperature in acetone and was washed in carbon tetrachloride. The piece was then dried for a few seconds in warm air, weighed, and introduced into the vacuum system. The sample was handled with tongs to prevent possible pickup of oil or moisture from the fingers. An average time of about 2 min was necessary to wash, dry, weigh, and introduce the sample into the analytical system.

Several small induction furnace heats were made to investigate the efficiency of hydrogen retention by the sampling devices and the accuracy of the hydrogen analyses. The method of testing was based on the solubility of hydrogen in liquid iron and has been described by Carney, Chipman, and Grant.[9] It involved the equilibration of a gas of known hydrogen pressure (mixtures of hydrogen and helium) with liquid iron in a controlled atmosphere furnace. The analyzed hydrogen content of samples taken directly from the furnace was compared to the value calculated from the hydrogen pressure of the gas and its solubility as determined by Sieverts[9] and by Liang, Bever, and Floe.[9]

The results of these tests indicated that the copper tube sampler, in combination with the analytical apparatus used, was capable of operation to an accuracy and precision within ±5 pct of the true hydrogen content of the liquid metal at the instant of sampling. The simple glass tube sampler showed somewhat less precision and for this reason the copper tube was preferred.

In the commercial furnace tests a question arises as to how representative of the furnace bath the liquid metal in the sampling spoon is. The accuracy of the spoon sampling procedure cannot be judged exactly. It was found, however, to give reproducible results when carried out in a careful manner. Of special importance in this regard was the need to prevent boiling in the spoon.

Concurrent with the sampling method used was the problem of preventing diffusion of hydrogen out of the samples from the time they were taken until they could be analyzed. The procedure used was to keep the samples in liquid nitrogen. The efficiency of liquid nitrogen storage was tested for 14 random samples including high and low carbon grades, both with and without low alloy additions of nickel,

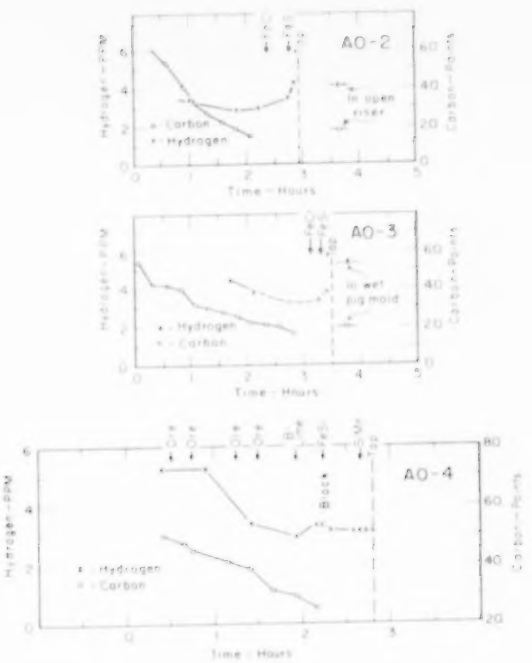

Fig. 4—Logs of acid heats AO 2, AO 3, and AO 4.

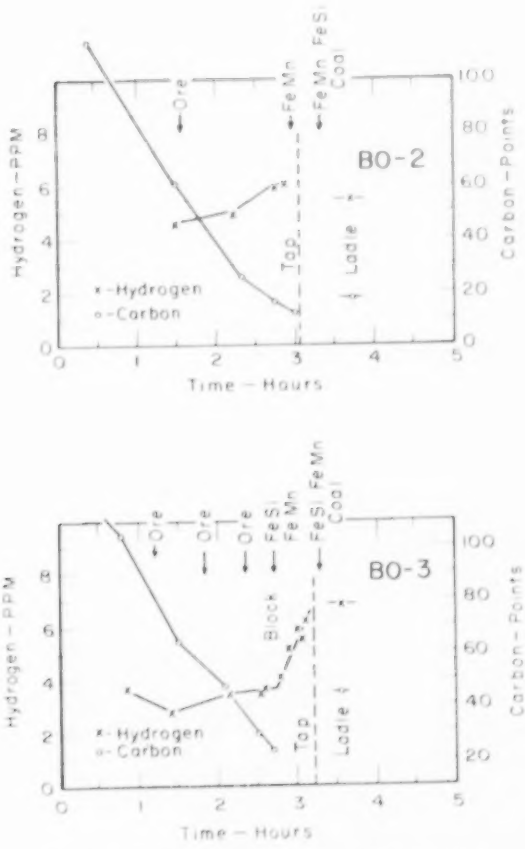

Fig. 5—Logs of basic open hearth heats BO 2 and BO 3.

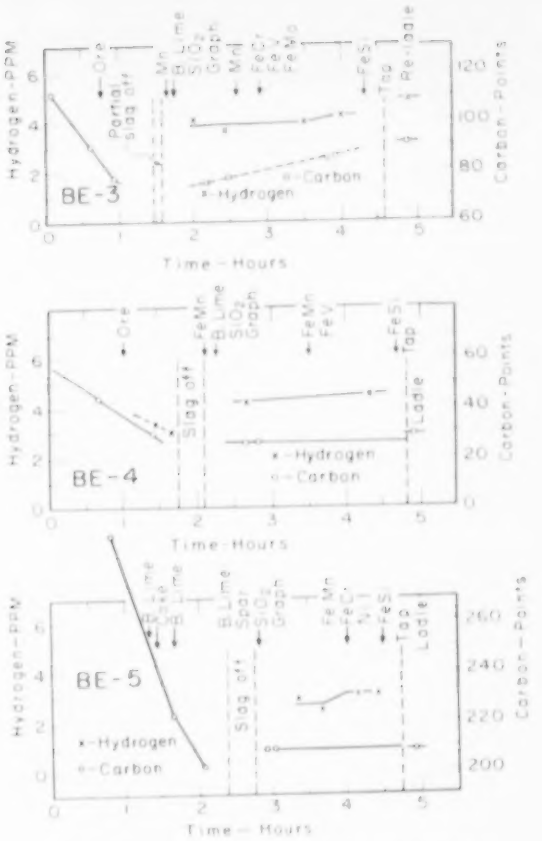

Fig. 6—Logs of basic electric heats BE 3, BE 4, and BE 5.

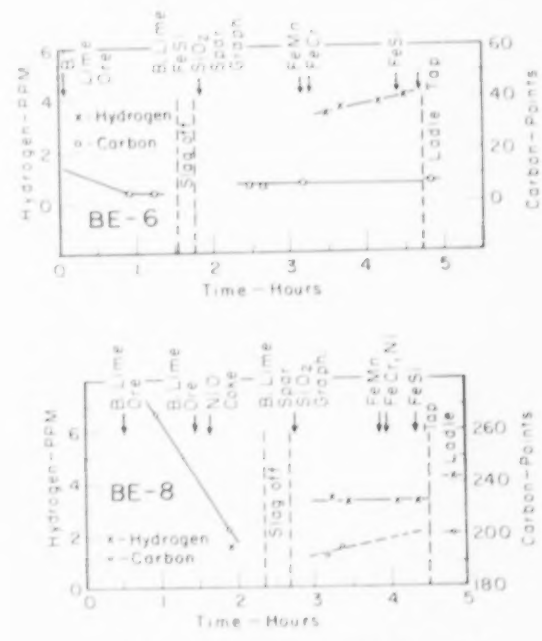

Fig. 7—Logs of basic electric heats BE 6 and BE 8.

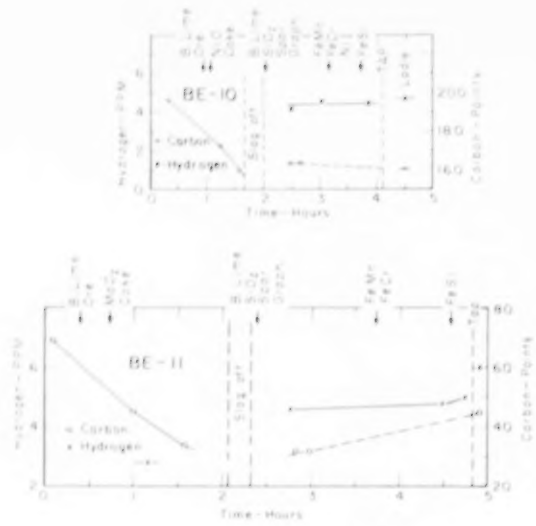

Fig. 8—Logs of basic electric heats *BE*-10 and *BE*-11.

chromium, and molybdenum. No significant change in the hydrogen content of these samples occurred in 65 days of storage in liquid nitrogen.

Another and somewhat incidental series of tests was carried out to investigate the effect on storage efficiency of steel composition and storage temperature. Three compositions, ingot iron, 12 pct Cr iron, and 18 pct Cr-8 pct Ni, were prepared as induction furnace heats. Samples of each composition were stored at room temperature (25°C), at dry ice-acetone temperature (−80°C), and at liquid nitrogen temperature (−196°C). Room temperature diffusion losses from the ingot iron and 12 pct Cr stainless samples were rapid. The hydrogen content of these grades dropped to about one half of their original value after 12 days of room temperature storage. In the case of the 18 pct Cr-8 pct Ni samples no significant losses were observed in 24 days of room temperature storage, indicating that room temperature storage is sufficient for austenitic grades. Storage at dry ice-acetone temperatures materially reduced the diffusion losses from the ingot iron and 12 pct Cr samples, but some disturbing variations in the hydrogen analyses were found. Apparently acetone was absorbed by the samples in some instances, leading to high analytical results. The conclusion was drawn, however, that samples could be safely stored at dry ice-acetone temperatures for periods of at least 12 days, provided such samples were absolutely sound or some means were taken to prevent acetone absorption. Again, the best results were obtained with liquid nitrogen storage, which prevented diffusion losses in all of these grades for periods up to 65 days. It should be noted that the samples under study here were roughly ¼ in. in diam.

Results of Sampling Commercial Heats

The main body of the experimental work consisted of sampling heats produced in commercial furnaces. Samples were taken throughout the course of three acid open hearth, two basic open hearth, and three basic electric two-slag heats, plus four additional basic electric heats during the reducing period only. The results are presented in the form of graphs showing the hydrogen and carbon contents during the heats and pertinent items from the heat logs, see Figs. 4 to 8. The acid open hearth heats, designated *AO*, were made in a 20-ton furnace using oil fuel with air atomization. The basic open hearth heats, designated *BO*, were made in 200-ton furnaces using oil and gas fuel with steam atomization. The electric furnace heats, designated *BE*, were made in 25 and 50-ton furnaces. Several additional heats were sampled just before tapping and through the teeming operation.

It is instructive, as well as convenient, in discussing the factors affecting the hydrogen content in the practices studied to consider each heat as divided into three separate periods: carbon oxidation, deoxidation, and tapping and teeming. The following discussion is based primarily on the heats sampled in this work but also leans heavily on the literature previously mentioned.

Hydrogen Content During Carbon Oxidation—In all the heats sampled, the hydrogen content of the liquid metal was lower at some time during the oxidizing period than at later stages. High initial hydrogen contents at meltdown were found to drop with the onset of the carbon oxidation reaction. The evolution of CO gas bubbles formed by carbon oxidation obviously flushed hydrogen out of the bath. However, in the fuel-fired heats at least, the hydrogen content did not continue to drop indefinitely as CO evolution continued. Rather, the hydrogen content tended to approach a fairly constant low value (not zero) which was maintained low only as long as carbon oxidation occurred at a sufficiently high rate. Low initial hydrogen contents at meltdown were maintained low only at sufficiently high carbon oxidation rates. If the rate of carbon oxidation decreased, the hydrogen content was generally found to increase.

The importance of carbon oxidation in obtaining low hydrogen heats cannot be denied because the flushing action provided by the CO evolution appears to provide the only means in normal practice of removing hydrogen from the bath. However, the effectiveness of the flushing action in obtaining low hydrogen content varies widely from practice to practice. This is evident from the fact that carbon oxidation rates of 0.50 pct per hr were necessary to lower the hydrogen content of the basic open hearth heats much below 4 ppm while similar hydrogen contents in acid open hearth heats were obtained at carbon oxidation rates of only 0.20 pct per hr. Also, the hydrogen contents at the end of the oxidation period of basic open hearth heats were considerably higher than found in the basic electric heats, even though made under similar slags and comparable carbon oxidation rates. Consider heats *BO*-2 and *BE*-8, for example. These were both subjected to a carbon oxidation rate of 0.50 pct per hr for 2 hr. At the end of this time the basic open hearth heat still had a hydrogen content greater than 4 ppm, while the hydrogen content of the basic electric heat was under 2 ppm.

The variation in the effectiveness of the flushing action in obtaining low hydrogen content from practice to practice, and the tendency for the hydrogen content to rise as the rate of CO evolution decreased, indicate that extensive hydrogen absorption was occurring even as dissolved hydrogen was being removed by CO evolution. That hydrogen absorption occurs is of prime importance. It means that the hydrogen content of the bath is controlled by the difference between the rate of hydrogen absorption

and the rate of hydrogen removal rather than by the rate of removal alone. In order for the hydrogen content to drop, the rate of carbon oxidation must be sufficient to provide enough flushing action to overcome the rate of hydrogen absorption. The fairly constant low hydrogen content frequently found for long periods during refining must be considered to represent a balance between these two rates rather than a static condition.

That hydrogen absorption occurs is not surprising in view of the substantial quantities of water vapor present in the furnace. The products of combustion of an open hearth flame contain 15 to 25 pct water vapor by volume. The moisture content of ore, limestone, or other slag additions often exceeds 5 pct by weight. Even atmospheric air leaking into the furnace may contain 6 pct moisture by volume on a humid summer day. The absorption of only 8.2 g of water in a ton of steel would increase the hydrogen content by 1 ppm, and it is known that water vapor coming in contact with liquid steel is readily reduced to hydrogen and absorbed. If it be granted that hydrogen absorption occurs, then the variation in the role of carbon oxidation from practice to practice, and even within a given practice, is readily explained. The lower hydrogen content in the basic electric practice at the end of the oxidizing period as compared to the basic open hearth practice is attributed to the lower moisture content of the electric furnace atmosphere.

The lower carbon oxidation rates necessary to give low hydrogen contents in acid open hearth as compared to basic open hearth practice are attributed to a lower hydrogen absorption rate provided by acid slag. Recent work has confirmed the solubility of water in slags[9] and supports the findings of Wentrup et al.[10] that acid slags contain less dissolved hydrogen than basic slags in commercial practice. The slag apparently acts as an imperfect barrier between water introduced into the furnace and the liquid bath in a manner similar to the effect of the slag on oxygen transfer to the bath.

Direct additions of ore to the slag increased the rate of oxygen absorption by the bath. If the ore added contained moisture, it would have undoubtedly increased the rate of hydrogen absorption by the bath as well. However, the effect of moisture in ore additions on the bath hydrogen content may not become immediately apparent because the ore also increases the rate of carbon oxidation and thus the rate of hydrogen removal as well. Moisture, in slag additions such as burnt lime, which does not particularly accelerate the rate of carbon oxidation, may have a directly noticeable effect on the hydrogen content, especially if made toward the end of

Fig. 9—Limiting hydrogen content of liquid iron under atmospheres containing water vapor at 1600°C.

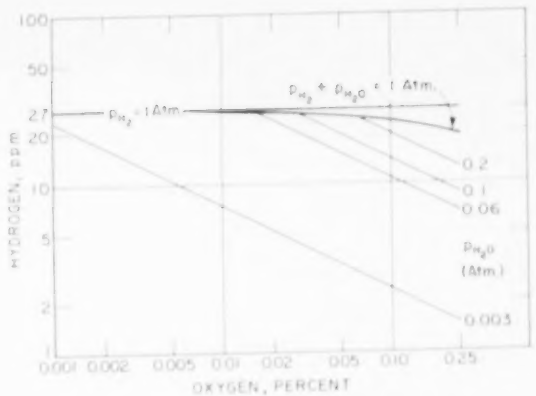

Fig. 10—Maximum hydrogen content in carbon-free metal under slag exposed to water vapor.

the heat. Quantitative estimates of the apparent rate of hydrogen absorption in the heats studied (to be presented in detail) indicated that this rate may vary markedly, even within a given practice. It was felt that these variations may be largely due to variations in the size and moisture content of slag additions.

Effect of Deoxidation—The increase in the hydrogen content of the acid and basic open hearth heats as the rate of carbon oxidation decreased was generally accentuated upon full deoxidation in the furnace. Such an increase must be expected because there is no longer any CO evolution to remove the hydrogen as it is absorbed by the bath.

In several cases some hydrogen was undoubtedly supplied by the deoxidation additions themselves. Analyses performed by Piper et al.[9] showed that ferroalloys may contain considerable hydrogen, either as dissolved hydrogen or as adsorbed water. In this regard, preheating the alloys before addition has been suggested. However, some of the increases in hydrogen content seem inconsistent with the small weight of the usual addition, indicating that hydrogen may also have been supplied by continuing reduction of water dissolved in the slag.

The rate of absorption of hydrogen dissolved in the slag under blocked conditions was investigated in one acid and one basic open hearth heat by holding them in the furnace for about 30 min after blocking in order to magnify the effect. The hydrogen content of the basic heat, No. *BO*-3, which was blocked by an addition of ferrosilicon and ferromanganese, increased at a steady rate from 3 to 6 ppm in this time. This increase was not thought to be due to hydrogen contained in the alloy because the hydrogen content in the ladle was found to be only slightly higher than just previously found in the furnace, although another similar addition was made in the ladle. The conclusion was drawn that hydrogen present in the slag was absorbed by the bath at a rate of about 0.1 ppm per min. Such an effect was not found in the acid heat, No. *AO*-4, which was blocked initially by a ferrosilicon addition and then by an addition of silicomanganese. The hydrogen content did not rise appreciably on blocking this heat. Note that the alloys added in this case were preheated. These results confirm the previous observation that the rate of hydrogen absorption by the bath is considerably slower under acid slags than under basic slags.

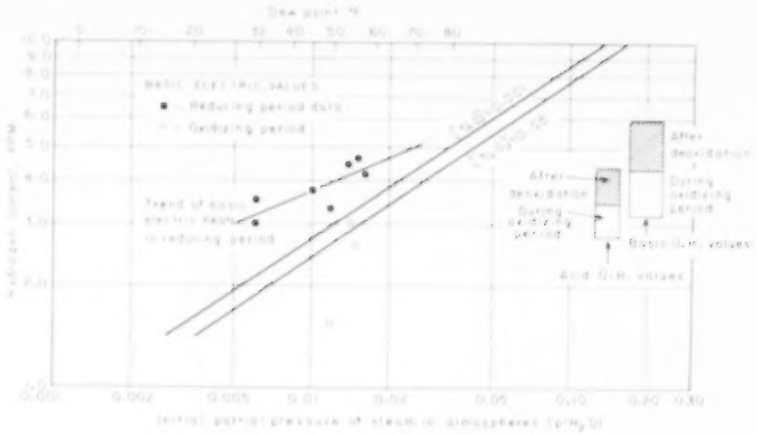

Fig. 11—Relation of experimental data to limiting hydrogen content.

The basic electric heats were blocked at the desired carbon level by slagging off the oxidizing slag and replacing it with a reducing type slag. The reducing slag was formed in usual fashion by adding burnt lime, sand, and graphite to the clear melt. The hydrogen content was found to increase sharply 1 to 3 ppm on performing this operation. This rapid increase was undoubtedly due to the moisture contained in the additions and points up the danger of adding moist materials. Barraclough[1] and Piper[5] reported that this increase could be held to a minimum by drying the additions thoroughly, especially the burnt lime. In the practice studied, this increase precluded the attainment of very low hydrogen content at tap. During the remainder of the reducing period, no significant change in the hydrogen content was observed. Any slight increase seemed to be associated with alloy additions. The constant hydrogen content found during the reducing period in the basic electric practice is in sharp contrast to the increase found under reducing conditions in the basic open hearth case. This difference is again attributed to the lower moisture content of the electric furnace atmosphere. A tendency was found for the hydrogen content of the electric furnace heats, at tap, to be somewhat dependent upon the atmospheric humidity, as will be discussed in a later section.

Table II. Average Values of Hydrogen Content at Tap for Acid and Basic Open Hearth and Basic Electric Two-Slag Steels

Hydrogen Content, Ppm				
Acid Open Hearth	Basic Electric	Basic Open Hearth	Authors	Sampling Method
5.9 (69)*	8.1 (8)	8.5 (19)	Wentrup[6]	Quartz tube-suction
4.8 (11)	5.6 (14)	—	Sykes[2]	Water cooled, pencil-poured
3.1 (3)	2.8, 5.9 (2)	4.6 (1)	Carney[3]	Copper tube-suction
2.2 (2)	2.6 (4)	3.4 (7)	Sims[4]	Copper mold-poured
—	3.3 (3)	5.9 (23)	Piper[5]	Quartz tube-suction
4.7 (46)	4.1 (46)	—	Barraclough[1]	Copper tube-suction
3.8 (4)	6.6 (7)	5.6 (3)	This work	Copper pencil-poured

* Number of heats in parentheses.

Effect of Tapping and Teeming—In every killed heat sampled, the hydrogen content was found to be higher in the ladle than just previously found in the furnace, illustrating once again the tendency for the hydrogen content of deoxidized steel to rise with time. The increase averaged 0.5 ppm. It is clear that moisture or hydrogenous materials contained in runner and ladle refractories and ladle additions may result in hydrogen absorption. In one series of tests during which no ladle additions were made, a killed heat tapped into a newly lined ladle showed a hydrogen increase of 1.0 ppm. On the third use of this ladle, the rise was only 0.3 ppm. This substantiates previous reports of the danger of hydrogen pickup from moisture in newly lined ladles. Increases in the hydrogen content of as much as 2 ppm have been reported in the literature due to wet refractories and hydrogenous ladle additions (notably coal). The effect of wet refractories was shown again in heat *AO*-3, in which the hydrogen content rose 1.5 ppm when the heat was teemed into a wet pig mold. A further series of tests showing the effect of moisture in the mold wash and hydrogenous mold coatings is shown in Table I. Five molds were teemed from the same ladle in rapid succession and samples taken from the open tops immediately upon filling were analyzed for hydrogen. Samples from a very heavily tarred steel mold showed an average hydrogen content of 8 ppm compared to 4 ppm for clean steel molds of exactly the same shape and size. Samples from a dry sand mold showed about the same hydrogen content as samples from the clean steel molds, whereas samples from a green sand mold contained slightly higher hydrogen.

Heat *BO*-2, a semikilled heat, showed a lower hydrogen content in the ladle than just previously found in the furnace. This heat could have lost hydrogen by continuing CO evolution. However, Barraclough[1] reported that a loss of 0.3 to 0.7 ppm was noticed repeatedly on tapping killed grades when the runner, ladle, and nozzle were thoroughly dried. Such losses were seldom found by other authors, presumably because the necessary drying of the ladles and refractories was not accomplished. Calculations of the effect of atmospheric moisture on the hydrogen content of steel, see below, support the explanation for the losses given by Barraclough that hydrogen may be oxidized from the metal during exposure to the atmosphere surrounding the pouring stream provided the atmospheric humidity is low enough. Conversely, the calculations confirm that hydrogen may be absorbed from the atmosphere surrounding the pouring stream if the atmospheric humidity is too high. It is thought that such effects are probably small.

Summary of Experimental Results

The experimental results indicate that the behavior of the hydrogen content during the course of

the heat is controlled by the difference between the rates of two opposing processes—hydrogen absorption from the slag due to moisture present in the furnace, and hydrogen removal from the metal due to gas evolution. Increased moisture content in the furnace atmosphere increased the rate of hydrogen absorption. The slag acts as a protective blanket and at the same time as a reservoir for moisture introduced into the furnace, acid slags being more effective protectors of the bath than basic slags. Increased rates of carbon oxidation increased the rate of hydrogen removal. In the absence of carbon oxidation, hydrogen content was noted to rise.

The average value of the hydrogen content at tap reflects the net effect of the factors noted. Table II summarizes the values obtained in the more recent investigations of the three practices studied. These are in agreement in showing that acid open hearth steels generally contain the least hydrogen, two-slag basic electric steels contain more, and basic open hearth steels have the highest hydrogen content at tap. Differences in the absolute values may be attributed in part to variations in the practices and to the experimental methods used. Of the results listed, Wentrup et al.[9] reported higher hydrogen contents and Sims et al.[10] lower values than found in this work.

The remaining portions of this paper are devoted to an attempt to place the experimental results on a fundamental and quantitative basis.

Thermodynamic Information

A partial understanding of the behavior of hydrogen in the metal bath may be attained through consideration of the limiting conditions imposed by equilibrium in the reaction of an atmosphere containing hydrogen and water vapor with liquid iron.

Gaseous hydrogen dissolves in liquid iron according to the reaction

$$\tfrac{1}{2}\,H_2\,(gas) = H\,(dissolved)$$

$$[H] = K_H\,(p_{H_2})^{1/2} \qquad [1]$$

When [H], the concentration of dissolved hydrogen, is measured in parts per million, and p_{H_2}, the partial pressure of hydrogen, is measured in atmospheres, the equilibrium constant K_H has a value of 27 at 1600°C. The expression for the concentration of dissolved hydrogen is the familiar Sieverts' law. The equilibrium constant may be expressed as a function of absolute temperature for pure liquid iron as $\log K_H = -1670/T + 2.32$.

Water vapor is the predominantly stable state for hydrogen in the furnace atmosphere existing above the slag because of the relatively high oxygen pressures prevailing. However, if water vapor comes in contact with the liquid metal, it is locally reduced to hydrogen to conform to the equilibrium

$$H_2O\,(gas) = H_2\,(gas) + O\,(dissolved$$

$$p_{H_2O}/p_{H_2} = K_{H_2O}\,[\%\ O] \qquad [2]$$

The value of the constant, K_{H_2O}, is approximately 4 at 1600°C and may be expressed as a function of absolute temperature for pure liquid iron as $\log K_{H_2O} = 7050/T - 3.17$.

The foregoing equations are not directly applicable to the nonequilibrium conditions met with in steelmaking practice. It is obvious that complete equilibrium of the metal bath with the gases flowing through the furnace is never achieved, since this would involve conversion of all the metal into slag. Nevertheless, it is possible to visualize certain conditions in which the limiting hydrogen concentration in the bath can be calculated from consideration of partial equilibrium. The use of the above equations in fixing the limiting hydrogen content under certain simplifying conditions will be illustrated in the following hypothetical cases.

When the bath is exposed to a limited flow of gas and the gas composition tends to adjust itself to that of the steel, the limiting hydrogen content is calculable. Let a mixture of steam and inert gas be brought into contact with a bath whose oxygen content is fixed, as for example by the presence of manganese or silicon. Let p'_{H_2O} represent the initial partial pressure of steam in the entering gas. At a given fixed total pressure the steam is reduced by reaction with the liquid metal according to the partial pressure balance

$$p'_{H_2O} = p_{H_2} + p_{H_2O}.$$

Then by Eqs. 1 and 2

$$p'_{H_2O} = [H]^2/K^2_H\,(1 + K_{H_2O}\,[\%\ O]). \qquad [3]$$

It is convenient to define a quantity, L, such that

$$L^2 = K^2_H/(1 + K_{H_2O}\,[\%\ O])$$

so that Eq. 3 becomes

$$[H] = L\,(p'_{H_2O})^{1/2}. \qquad [4]$$

The relationship given in Eq. 4 between limiting hydrogen and oxygen contents and the initial steam pressure is shown in Fig. 9 for a temperature of 1600°C. It is pointed out that the calculation is made for a carbon-free system. The diluting effects of CO and CO_2 will be considered later.

A slightly different situation arises if a mixture of steam and inert gas is blown over the surface of the slag which covers a bath of carbon-free metal. Since steam is soluble in the slag, the metal is effectively exposed to steam at its initial pressure in the gas stream. At the same time the hydrogen formed by reduction of H_2O at the slag-metal interface cannot diffuse through the slag and its pressure may be built up to higher levels. The limiting hydrogen content is obtained by directly combining Eqs. 1 and 2.

$$H_2O\,(gas) = 2\,H\,(dissolved) + O\,(dissolved)$$

$$K_{H_2O} = [H]^2 \times [\%\ O]/p_{H_2O} \qquad [5]$$

The equilibrium constant for reaction 5, K_{H_2O}, at 1600°C, is 183 and, expressed as a function of temperature, is $\log K_{H_2O} = -10{,}390/T + 7.81$. This relationship is the case previously considered by Carney, Chipman, and Grant,[7] and is shown in Fig. 10.

It is evident that the foregoing cases do not represent actual steelmaking conditions exactly. However, the experimental data obtained bear a close relation to the formulation developed in Eq. 4, which is taken as a measure of the limiting hydrogen content under the observed conditions. This is shown in Fig. 11 by plotting the experimental hydrogen content against a background of lines representing Eq. 4. Note that the acid open hearth heats are plotted at a nominal water vapor pressure of 0.15 atm, corresponding generally to an air-atomized oil flame. The basic open hearth heats are plotted at a nominal steam pressure of 0.20 atm, corresponding to a steam-atomized oil flame. The

Table III. Calculations of Apparent Hydrogen Absorption Rates

	Hydrogen Analysis Data					Carbon Analysis Data					
						Points					
	H_1, Ppm	H_2, Ppm	Δt, Min	H_{av}, Ppm	$\frac{\Delta[H]}{\Delta t}$ obs, Ppm per Min	C_1	C_2	Δt, Min	$\frac{\Delta C}{\Delta t}$, Points per Hr	Calculated Rate of H_2 Removal, Ppm per Min	Apparent Hydrogen Absorption Rate, $\frac{\Delta[H]}{\Delta t}$, Ppm per Min
Heats Studied in This Work											
Acid Open Hearth Practice											
AO-2	3.3	2.8	50	3.05	+ 0.010	32	18	45	18.7	0.070	0.060
	2.8	(steady)		2.8	0	22	14	30	16	0.050	0.050
AO-3	4.5	3.9	25	4.2	+ 0.024	28	22	30	12	0.085	0.061
AO-4	5.3	3.6	60	4.3	+ 0.029	45	30	60	15	0.110	0.081
	3.2	(steady)		3.2	0		(blocked)		—	0	0 (very low)
Basic Open Hearth Practice											
BO-2	4.6	5.6	45	4.8	+ 0.009	60	30	50	36	0.330	0.339
	5.9	6.9	30	5.5	+ 0.033	39	12	40	27	0.330	0.363
BO-3	3.7	2.8	35	3.3	+ 0.026	104	64	43	56	0.244	0.22
	2.8	3.5	42	3.2	+ 0.016	64	47	34	30	0.130	0.146
	3.5	(steady)		3.5	0	47	23	38	38	0.187	0.187
	3.5	6.2	32	5.0	+ 0.081		(blocked)		0	0	0.081
Basic Electric Practice, Oxidizing Period											
BE-4	2.3	3.0	13	3.15	0.023	44	30	45	19	0.076	0.053
BE-8	1.5	(steady)		1.5	0	247	202	57	48	0.043	0.043
BE-11	2.8	(steady)		2.8	0	69	34	90	23	0.070	0.07
Heats Reported by Piper et al.[5]											
Basic Open Hearth Practice											
Fig. 3	3.4	2.3	55	2.9	+ 0.022	140	110	55	33	0.111	0.089
4	2.3	2.7	45	2.5	+ 0.009	110	77	45	44	0.111	0.110
	2.7	3.6	25	2.85	+ 0.012	77	58	25	46	0.150	0.160
	3.6	3.6	25	3.3	+ 0.24	58	49	25	22	0.097	0.121
4	4.5	3.8	55	4.2	+ 0.013	64	32	55	35	0.244	0.231
	3.8	4.3	25	4.6	+ 0.016	32	22	25	24	0.155	0.171
	4.2	5.0	25	4.6	+ 0.032	22	12	25	24	0.205	0.237
	5.0	5.6	20	5.3	+ 0.03	12	8	20	12	0.136	0.166
5	3.0	3.7	30	3.4	+ 0.023	96	83	30	26	0.118	0.141
	3.7	3.2	35	3.5	0.014	83	70	35	22	0.105	0.091
	3.2	4.0	20	3.6	+ 0.04	70	62	20	24	0.126	0.166
	4.0	2.7	25	3.4	0.052	62	50	25	29	0.135	0.083
6	3.7	4.6	60	4.2	+ 0.015	40	17	60	23	0.161	0.176
	4.6	5.0	30	4.8	+ 0.013	17	12	30	10	0.093	0.106
	5.0	6.4	20	5.8	+ 0.07	12	8	20	12	0.159	0.229
6	3.2	2.7	65	3.0	0.008	87	42	65	42	0.148	0.141
	2.7	4.0	25	3.4	+ 0.052	42	37	25	12	0.056	0.108
	4.0	5.6	20	4.5	+ 0.05	37	28	20	27	0.220	0.270
	5.0	5.8	15	5.4	+ 0.053	28	21	15	28	0.328	0.381
Basic Electric Practice, Oxidizing Period											
7	2.7	(steady)		2.7	0.02 (est)	99	22	60	77	0.228	0.205
7-a	2.7	(steady)		2.7	0.01 (est)	70	50	95	13	0.037	0.027
7-b	3.3	(steady)		3.3	0	65	20	115	24	0.107	0.107
7-c	3.6	2.7	90	3.2	0.01	90	38	90	35	0.142	0.132
8	3.6	(steady)		3.6	0	90	40	45	67	0.350	0.350

basic electric heats are plotted against the atmospheric humidity determined from the dew point at the time the heat was made (obtained from the local U. S. Weather Bureau).

During the oxidizing period of the heats, the hydrogen contents were maintained below the calculated value as would be expected due to the flushing action provided by CO evolution. The hydrogen content rose toward the calculated values in the acid and basic open hearth practices when the heats were deoxidized. The calculations predict that the hydrogen content of the basic and acid open hearth heats would eventually rise to a value of about 11 ppm if held under deoxidized conditions for a sufficient time. On the other hand, the addition of the reducing slag materials to the basic electric heats raised the hydrogen content close to but slightly above the calculated value, and no further increase is predicted, as was found experimentally. This figure brings out another interesting point about basic electric furnace heats; namely, a trend toward higher hydrogen content at tap when the atmospheric humidity is high. This may be due as much to the burnt lime added as to any direct effect of the furnace atmosphere, since lime tends to absorb more water on moist days.

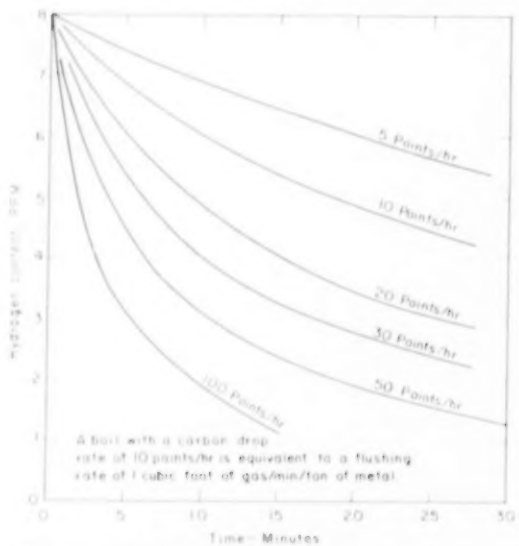
5 Points/hr
10 Points/hr
20 Points/hr
30 Points/hr
50 Points/hr
100 Points/hr
A bath with a carbon drop rate of 10 points/hr is equivalent to a flushing rate of 1 cubic foot of gas/min/ton of metal
Time - Minutes

Fig. 12—Theoretical flushing curves showing effect of carbon oxidation on hydrogen content in the absence of hydrogen absorption.

Calculation of Flushing Action Provided by Carbon Oxidation—The thermodynamic formulation culminating in Eq. 4 was used to show how much hydrogen could be dissolved in liquid iron from an atmosphere containing water vapor and hydrogen in the absence of any slag layer. It can also be applied to the reverse case of eliminating hydrogen by the flushing action provided by gas evolution. In the following calculation, it is assumed that the flushing action of gas evolution is theoretically perfect and limited only by equilibrium considerations.

Consider a given bubble of gas evolving at the surface of the bath which contains CO, CO_2, H_2, and

H_2O as its main constituents. By the ideal gas laws, the volumes, dV, of the constituents bear the following relation to the partial pressures

$$\frac{dV_{H_2} + dV_{H_2O}}{dV_{CO} + dV_{CO_2}} = \frac{p_{H_2} + p_{H_2O}}{p_{CO} + p_{CO_2}} = \frac{p_{H_2} + p_{H_2O}}{P_t - (p_{H_2} + p_{H_2O})}.$$

The term P_t is the total pressure of the emerging bubble, and the term $p_{H_2} + p_{H_2O}$ is equivalent to the quantity defined as p'_{H_2O}, except that in this case it is the water vapor pressure of the emerging bubble rather than of the entering gas. Each bubble of gas containing $dV_{H_2} + dV_{H_2O}$ depletes the bath by d [H] ppm H.

$$dV_{H_2} + dV_{H_2O} = \frac{-d\,[H] \times W \times 359}{2 \times 10^4},$$

Each bubble of gas containing $dV_{CO} + dV_{CO_2}$ depletes the bath by d [C] points of carbon.

$$dV_{CO} + dV_{CO_2} = \frac{-d\,[C] \times W \times 359}{12 \times 10^4}$$

where W equals the weight of the bath in pounds.

Substituting the foregoing relations in Eq. 3 gives the relation between the amount of hydrogen removed and the amount of carbon oxidized.

$$\frac{d\,[H]}{d\,[C]} = 16.6 \frac{[H]^2}{L P_t - [H]^2}. \qquad [6]$$

Differentiating with respect to time, assuming the total pressure equals 1 atm, noting that $[H]^2$ is much smaller than L, choosing a value of L equal to 26.5 (an average for 1600°C and oxygen contents from 0 to 0.05 pct), the following equation governing the rate of hydrogen removal, as affected by a given rate of carbon oxidation under typical practice conditions, may be written

$$\frac{-d\,[H]}{dt} = 4 \times 10^{-4} \times [H]^2 \times \frac{d\,[C]}{dt} \qquad [7]$$

where $\frac{-d\,[H]}{dt}$ is the rate of hydrogen removed in ppm per min, $\frac{d\,[C]}{dt}$ is the rate of carbon oxidation in pct per hr, and [H] is the hydrogen content in ppm.

Integration of Eq. 7 for constant values of $\frac{d\,[C]}{dt}$ results in the relation between hydrogen content and time plotted in Fig. 12. These curves show how the hydrogen content would drop under various rates of carbon oxidation if no hydrogen were being absorbed by the bath.

Rate of Hydrogen Absorption—The rate of hydrogen absorption can be calculated from a simple material balance:

Rate of hydrogen absorption = change in hydrogen content per unit time + rate of hydrogen removal.

The change in hydrogen content per unit of time can be obtained from a series of hydrogen analyses of the bath; the rate of hydrogen removal may be estimated from Eq. 7. This was done for the heats

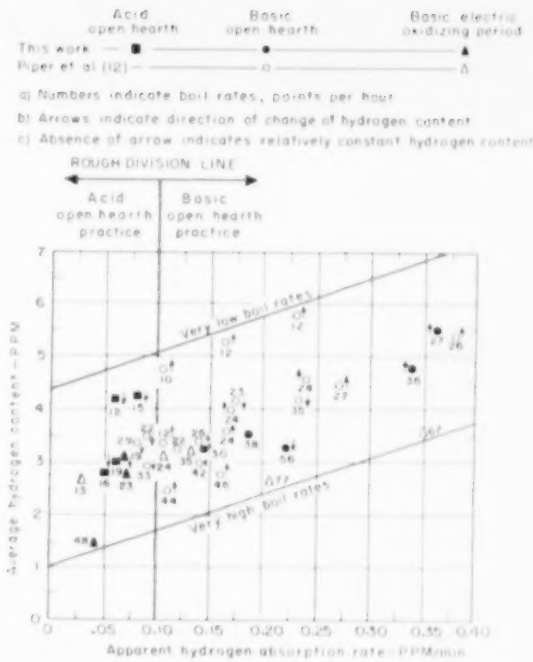

Fig. 13—Average hydrogen content vs apparent hydrogen absorption rate during oxidation period.

studied in this work and those reported by Piper et al.[12] as shown in Table III. The results are plotted in Fig. 13, which shows the average hydrogen content plotted against the calculated rate of hydrogen absorption. The numbers beside the points indicate the carbon oxidation rate and the arrows indicate the direction of change of the hydrogen content.

The hydrogen absorption rate in acid open hearth practice is lower than in basic open hearth practice. In the acid practice, the hydrogen absorption rates were found to be less than 0.10 ppm per min. In basic open hearth practice hydrogen absorption rates under 0.10 ppm per min were rarely found, and absorption rates as high as 0.35 ppm were encountered. The hydrogen absorption rates found in basic electric practice were also found to be low. However, Piper et al.[12] indicated that this may not necessarily have been so in all cases.

Two other important points are apparent:

1) At a given absorption rate, higher carbon oxidation rates produce lower hydrogen content. This is shown by the carbon oxidation rate numbers, which increase in going from high to low hydrogen content on any vertical line in Fig. 13. This decrease of hydrogen content with increasing carbon oxidation rates shows the independent effect of gas evolution.

2) Higher hydrogen absorption rates are associated with higher rates of carbon oxidation. This is shown in Fig. 13 by the increase in the carbon oxidation rate numbers on going from low to high absorption rates at any given hydrogen content. This increase of the absorption rate with increasing carbon oxidation rate is believed to be the result of two effects; namely, the increased boil rates, which cause more intimate mixing of the slag, metal, and furnace gases, and introduction of moisture with heavy ore additions, which also causes increased boil rates. Unfortunately, no direct test of this latter

postulation has been carried out to the authors' knowledge.

Conclusions

The behavior of hydrogen in steelmaking furnaces is controlled by the difference between the rate of hydrogen absorption from moisture introduced into the furnace and the rate of hydrogen removal due to carbon oxidation. Reducing the amount of moisture from all possible sources would tend to decrease the rate of hydrogen absorption and thus result in lower hydrogen content. Increasing the rate of carbon oxidation without increasing the rate of hydrogen absorption would result in lower hydrogen content.

In the absence of rapid carbon oxidation, the hydrogen content increases. Drying all additions made after deoxidation and refraining from the use of hydrogenous addition would result in lower hydrogen content. In basic open hearth practice, reducing the time under blocked conditions and avoiding complete deoxidation in the furnace would tend to reduce the hydrogen content. The tendency for the hydrogen content of killed steels to rise during tapping and teeming is important, and precautions concerning moisture in refractories and contact with hydrogenous materials should be exercised.

An attempt has been made to place the effect of moisture in the furnace atmosphere and the effect of the carbon oxidation reaction on a quantitative basis. These calculations seem to offer a reasonable explanation of the results observed in the present work and a substantiation of the conclusions of Sims, Piper, von Hofsten, Kalling, and their coworkers.

Acknowledgments

The authors wish to thank T. B. King and Roger Franklin for their assistance with this research work. They also wish to express their appreciation to the Office of Naval Research and the American Iron and Steel Institute for their sponsorship, and the Timken Roller Bearing Co. for assistance with the extensive chemical analysis program. This paper is based on a portion of a thesis by Henry Epstein submitted in partial fulfillment of the requirements for the degree of Doctor of Science to Massachusetts Institute of Technology.

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Selective Sulfation for Cadmium Recovery At Josephtown Smelter

Investigation of the autogentic sulfation of cadmium oxide by zinc sulfate has disclosed the existence of a sulfation series in which sulfates higher in the series will, upon heat treatment of a mixture, sulfate oxides of metals lower in the series. An early commercial application of this research at Josephtown Smelter is described.

by R. E. Lund and D. E. Warnes

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SELECTIVE sulfation of individual constituents in ores or metalliferous products has received increased attention in recent years. The fluid-bed reactor with its advantages of close control of both temperature and atmosphere promises to have ap-

plication for treatment of complex ores; older sulfation techniques include acid leaching and baking with sulfuric acid. As generally applied, these several methods of sulfation require the use of compounds containing considerable excess sulfur relative to that reporting in soluble products, and application to fume products may have undesirable or complicating features. It is the purpose of this paper to describe the test work and the commercial application of a different method of selective sulfation by which excess sulfur is not required and whereby the cadmium content of a smelter fume is rendered water soluble while at the same time the accompanying zinc, iron, and arsenic are made insoluble.

Former Practice—At Josephtown Smelter, cadmium is recovered from fume produced in the sintering of desulfurized zinc concentrates. Former cadmium recovery practice consisted of leaching the fume with byproduct weak acid (sulfuric), displacing a crude cadmium sponge of slime-like characteristics from neutral solutions by the addition of zinc dust, roasting the crude sponge, releaching with product sulfuric acid, and cementing a briquettable grade cadmium sponge on super high grade zinc slabs.

Table I. Cadmium Solubility as a Function of Temperature

Temperature, °C	Water Soluble Cadmium, Pct
450	68
550	73
650	83
750	86
850	77

Appreciable concentrations of sulfite and dithionate compounds, a consequence of the relatively high reduced-sulfur content of the cadmium fume and of the drip acid (effluent from SO_2 gas purification) used in leaching, were present in leach solutions. The presence of these compounds caused a considerable portion of cadmium to precipitate as cadmium sulfide when zinc dust was added to solutions. The same compounds were also apparently responsible for a high rate of cadmium resolution occurring during filtering of sponge. Effective control of impurities throughout the circuit was lacking with the result that cadmium sponge obtained from the second stage of cementation was sometimes of poor briquetting quality. Net effects of these circuit characteristics were low efficiency of cadmium recovery and lack of operational stability.

Preliminary Studies—A research project was started late in 1951 to study the cadmium circuit. Oxidation of leach solutions had been investigated on a small scale and found to effect major improvement in circuit characteristics. However, the high content of reduced sulfur compounds in the solutions made oxidation unattractive economically.

Tests were made to determine the effects of roasting the cadmium fume prior to leaching. This work indicated that roasting the fume to a well oxidized product would also effect improvement in circuit characteristics.

A review of notes which had been compiled on cadmium metallurgy during the early years of Josephtown Smelter produced a notation which stated that a solution of zinc sulfate would solubilize cadmium if the latter were in the oxidized state. Small scale tests were made and it was indicated that a zinc sulfate solution would apparently effect a high degree of cadmium extraction from oxidized fume.

Tests were conducted on a larger scale employing a rotary kiln for roasting the fume. However, poor cadmium extractions were obtained when these roasted products were leached with solutions of zinc sulfate.

A study was then made to determine why the cadmium fume which had been roasted at relatively low temperature in a laboratory muffle furnace yielded good cadmium extraction but fume which had been roasted in the rotary kiln at more elevated temperature yielded poor extraction.

It was found that a solution of zinc sulfate would solubilize cadmium oxide to a limited extent. More important, it was established that the high extractability of cadmium obtained from fume muffle roasted at low temperature is due to the fact that cadmium in the heat treated product is in the form of water soluble sulfate.

This phenomenon of autogenous sulfation then suggested the basis for a systematic investigation.

Selective Sulfation

At Josephtown Smelter cadmium bearing fume is collected by dedusting sintering machine gases in electrostatic precipitators. Average composition of fume is approximately 36 pct Zn, 7 pct Cd, 10 pct Pb, 2.5 pct Fe, 0.4 pct As, 10 pct total sulfur, and 4 pct sulfate sulfur.

A water leach of the raw fume disclosed that approximately 15 pct of the cadmium and 18 pct of the zinc were water soluble. However, when the fume was heat treated at a temperature of approximately 500 C for a period of 1 hr, water soluble cadmium increased to approximately 90 pct of the contained cadmium while water soluble zinc decreased to the order of 1 to 2 pct of the contained zinc.

Table II. Influence of Ratio of Zinc Sulfate to Cadmium Oxide With 1 Hr Heat Treatment at 550°C

Molar Ratio $ZnSO_4/CdO$	Water Soluble Cadmium, Pct
1	25
5	63
10	73
20	85

This experiment demonstrated that suitable heat treatment of the fume would selectively sulfate the cadmium and desulfate the zinc.

Study of Synthetic Mixtures

Since the complex composition of raw fume made difficult the definition of basic factors, the first work was to investigate reactions occurring in heat treated synthetic mixtures of various metallic sulfates and oxides. These mixtures were made by intimately mixing reagent grade components in the dry state. In each test several hundred grams of material were placed on a roasting dish and heat treated without rabbling in a muffle furnace. Atmosphere was open air.

Reaction between zinc sulfate and cadmium oxide was studied in some detail. In one series of tests a mixture containing 3.5 pct Cd as CdO, 35 pct Zn as ZnO, and 21 pct Zn as $ZnSO_4$ was heat treated for 1 hr at various temperatures. Typical variations of

cadmium solubility as a function of temperature are shown in Table I.

These data confirm that zinc sulfate will sulfate cadmium oxide. A temperature of 750°C was indicated as the most effective, although appreciable reaction took place at temperatures considerably below that at which zinc sulfate starts to decompose.

Tests were conducted to study the influence of the ratio of zinc sulfate to cadmium oxide upon cadmium solubility. Typical results with heat treatment for 1 hr at 550°C were as shown in Table II.

These data confirm, as theory would suggest, that cadmium solubility is improved as the ratio of zinc sulfate to cadmium oxide is increased.

Sulfation Series—Also investigated were the sulfating characteristics of other sulfates and oxides. Metallic sulfates and oxides studied included those of aluminum, iron, copper, zinc, cadmium, and lead. Mixtures were prepared containing one metallic sulfate and one or more of the oxides. Heat treating conditions were a temperature of 500° to 550°C and a residence period of 1 hr. This work disclosed that both ferrous and ferric sulfate would sulfate oxides of aluminum, copper, zinc, and cadmium. In one test a mixture containing 4.9 pct CdO, 3.1 pct CuO, 3.1 pct ZnO, 3.9 pct Al_2O_3, 20.7 pct silica flour, and 64.3 pct $Fe_2(SO_4)_3 \cdot H_2O$ was heat treated. A water leach extracted 99 pct of the zinc, 98 pct of the cadmium, 35 pct of the copper, and 18 pct of the aluminum.

Table III. Effect of Temperature on Formation of Cadmium Sulfate

Temperature, °C	Water Soluble Cadmium, Pct
240	48
350	70
400	79
450	82
500	82
650	80
750	68

Aluminum sulfate was found to be effective in sulfating oxides of cadmium, zinc, and copper, but not iron. Copper sulfate in turn was found to sulfate cadmium and zinc, but not aluminum or iron.

Lead sulfate was not effective in sulfating any of the oxides. Solubility of metals from heat treated mixtures which contained lead oxide were lower than from similar mixtures which contained no lead.

The results of this work indicate that the metals can be arranged in a sulfation series similar in its implication for selective sulfation to the electromotive series for displacement of metals from solution. For the metals which were studied the sulfation series listed in decreasing order for tendency to give up SO_3 is: $FeSO_4$, $Fe_2(SO_4)_3$, $Al_2(SO_4)_3$, $CuSO_4$, $ZnSO_4$, $CdSO_4$, and $PbSO_4$.

The sequence of metals in the above series corresponds with recorded temperatures for decomposition of the sulfates[1] if the data of Mostowitsch[2] for decomposition of $PbSO_4$ are accepted rather than those of Hofman-Wanjukow.[3] Results of these tests indicate that sulfates of iron, aluminum, copper, and zinc will solubilize cadmium. The significance of lead being lowest in the sulfation series is that lead is sulfated by cadmium. Accordingly, if cadmium is to be sulfated in a material containing lead, sufficient sulfate must be present to effect sulfation of both metals. This was confirmed in tests which were conducted with fumes containing appreciable lead.

Treatment of Cadmium Fume

Having defined the principle of autogenous cadmium sulfation in some detail, work was then undertaken to investigate methods for solubilizing the cadmium in raw fume. Samples of fume were heat treated to demonstrate the effect of temperature on formation of cadmium sulfate. As in previous tests, duration of heat treatment was 1 hr. Table III summarizes the results of this work.

The data indicate that a heat treating temperature of 400° to 650°C is probably optimum for maximum solubilization of cadmium in this species of fume.

A number of heat treating tests were conducted on samples of fume collected during differing periods. These tests consistently confirmed that more than 80 pct of the cadmium could be solubilized by heat treating for 1 hr at approximately 500°C. In many tests cadmium extractions exceeding 90 pct were obtained.

Optimum sulfation of cadmium in fume occurred at temperature somewhat lower than in synthetic mixtures which contained cadmium oxide, zinc oxide, and zinc sulfate. This behavior is likely due to:

1) Intimate association of fume constituents,

2) Oxidation of reduced sulfur compounds to sulfates, and

3) As a consequence of this oxidation, local temperatures in fume undergoing heat treatment are actually somewhat higher than indicated by pyrometer.

Tests were made to study influence of treatment time on cadmium sulfation. This work indicated that a minimum of 30 to 45 min at 500°C is required for attainment of maximum cadmium solubilization. No decrease in cadmium solubility was found with heat treatment for extended periods of time (maximum investigated, 6 hr).

A typical analysis of fume before and after heat treatment is shown in Table IV.

Characteristics of Leach Solutions—Solutions obtained by water leaching of heat treated fume contained approximately ten times as much cadmium as zinc. This compares with a ratio of about 0.19 cadmium to 1 zinc in raw fume.

Table IV. Typical Analyses of Fume Before and After Heat Treatment

	Pct Zn	Pct Cd	Pct Pb	Pct Fe	Pct As	Pct Total Sulfur	Pct Sulfate Sulfur
Raw fume	35.7	6.7	10.2	2.3	0.44	9.7	4.1
Heat treated fume	46.0	8.5	13.9	3.1	0.56	4.4	4.2

Solutions were remarkably free of impurities. A typical solution containing 40 g per liter Cd analyzed as shown in Table V.

As a result of this low impurity content, no purification of solutions is required prior to recovery of cadmium. Cadmium sponge produced by cementation with zinc is of excellent briquetting quality.

It was demonstrated that a slurry of heat treated fume has appreciable capacity to purify solutions contaminated with arsenic. A slurry of heat treated fume containing 40 pct solids when added to a solution of equal volume containing a couple of hundred milligrams arsenic per liter will reduce the arsenic

concentration to less than 1 mg per liter. This purifying capacity is probably due to the large excess of zinc oxide in the heat treated fume, which results in formation of an arsenic sequestering precipitate of basic zinc sulfate. Water solutions of heat treated fume have a pH of approximately 5.5.

Characteristics of Leach Residues—Tests were conducted to determine characteristics of the high zinc residues resulting from water leaching of heat treated fume. This work demonstrated that heat treatment improved amenability of solids to weak acid leaching. Treatment of the water leached residues with 50 g per liter sulfuric acid solutions extracted approximately 95 pct of the zinc and 85 pct of the residual cadmium. Less arsenic was solubilized as compared with similar leaching of raw fume.

Typical analyses of water leached residues before and after leaching with weak acid are shown in Table VI.

Proposed Process—Results of the test work which has been described indicated that substantial improvement could be effected in the overall leach circuit by selectively sulfating the cadmium fume. Plans accordingly were made to commercialize the process. The projected process was as follows:

1) Cadmium fume would be heat treated to convert cadmium to water soluble sulfate.

2) Heat treated fume would be leached with water in two counter current stages to yield pregnant solutions containing approximately 40 g Cd and 4 g Zn per liter.

3) Clarified pregnant solution would be treated without purification for recovery of cadmium sponge.

4) Water leached residues of heat treated fume would be leached with weak acid, and resulting solutions would be processed in the existing leach circuit.

Large Scale Tests—Particular steps in the new process were tested on a semicommercial scale. Cadmium fume was heat treated in a 21 ft 6 in. ID Nichols-Herreshoff furnace at throughput rates equal to and exceeding rate of fume collection from sinter machine gases. Results indicated that a four-hearth furnace of similar diameter would be sufficient for processing approximately 20 tons of fume per day.

Metallurgical results were satisfactory. More than 90 pct of the cadmium and less than 4 pct of the zinc was rendered water soluble by heat treatment. Optimum heat treating temperature was indicated to be 375° to 450°C.

Table V. Analysis of Typical Leach Solution Containing 40 G per Liter Cd

Metal	Concentration
Zn	4.1 g per liter
Pb	less than 0.05 g per liter
As	less than 1 mg per liter
Fe	0.05 g per liter

Several tons of heat treated fume were transferred to the Leach Plant for testing. Cadmium extractions of the order of 85 pct were obtained by two-stage water leaching.

Pregnant liquor was treated in cementation tanks for recovery of cadmium. Cementation rate was rapid and the sponge briquetted well. Specific gravity of briquettes was of the order of 6.0.

Water leached residues of heat treated fume were leached with weak sulfuric acid. Extraction of zinc and of residual cadmium checked results obtained from laboratory tests. The acid-leached solids had good settling properties and contained more than 40 pct Pb and less than 4 pct Zn.

Commercial Application

A plant to accommodate the new cadmium circuit was designed. Part of it has been completed and is now in operation. Major equipment items include an elevator-fed bin and rotary table feeder for metering cadmium fume to a four-hearth gas fired 21 ft 6 in. ID furnace of Nichols-Herreshoff type. Furnace off-gases are dedusted. A ball mill slurries the heat treated fume with water. When the rest of the circuit is completed this slurry will be dewatered on rotary vacuum filters. Filtrate will pass to conventional cementation tanks for production of briquette sponge.

Table VI. Typical Analyses of Water Leached Residues Before and After Leaching with Weak Acid

	Pct Pb	Pct Cd	Pct Zn	Pct As	Pct Fe
Water leached residue	17.7	1.2	52.9	0.64	3.6
After leaching with acid	42.0	0.3	4.0	0.60	8.3

The heat treatment portion of the circuit was placed in operation late in 1954. The furnace has consistently produced a well sulfated product. Water soluble cadmium has averaged more than 90 pct contained cadmium. Temperatures in the furnace are maintained at approximately 425°C.

Pending completion of circuit changes the heat treated fume is being processed by the conventional leach method. Perhaps the most dramatic comment to make on the improvement in operating results achieved is to compare recovery of cadmium in the leach circuit under the old system (63 pct for 1953) with experience using the partially completed new system (85 pct for the first nine months of 1955). Even higher recoveries are expected when the changeover is complete.

Acknowledgments

As is true with most commercial developments many people have participated in converting this process from a laboratory experiment to a commercial reality. Special mention should be made of the supervisors and operators in the Leach Plant and of the chemists in the Analytical Laboratory. Counsel with C. C. Long is gratefully recognized. Finally, acknowledgment is due John G. Wehn, Manager, Josephtown Smelter, for suggesting and encouraging presentation of this metallurgical information before completion of its commercial adaptation.

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Discussion of this paper sent (2 copies) to AIME by June 1, 1957 will appear in AIME *Transactions* Vol. 209, 1957, and in JOURNAL OF METALS, October 1957.

Remeasurement of Liquidus Temperatures of Mg-Ba Alloys

by K. P. Anderko

INVESTIGATIONS of the constitution of the system Mg-Ba were first made by Grube and Dietrich[1] between 0 and 47 atomic pct Ba and then by Klemm and Dinckelacker[2] over the whole composition range. Klemm and Dinckelacker corroborated intermediate phases of the approximate formulas Mg_3Ba and Mg_2Ba, and showed a third compound to have the formula Mg_5Ba_3, rather than Mg_3Ba_2, as suggested by Grube and Dietrich. Mg_2Ba had been previously recognized by Hellner and Laves[3] as a $MgZn_2$ (C14) type structure. The main discrepancies between the results of Grube and Dietrich and those of Klemm and Dinckelacker exist, however, in the liquidus temperatures and solidification equilibria of alloys containing more than about 10 atomic pct Ba. The liquidus temperatures measured by Grube and Dietrich, and the outline of the liquidus of Klemm and Dinckelacker are plotted in Fig. 1 on an enlarged scale. Although there are strong reasons to prefer the results of Klemm and Dinckelacker, it was considered worthwhile to remeasure liquidus temperatures of some alloys in the controversial composition range.

Table I. Compositions and Liquidus Temperatures of Mg-Ba Alloys Prepared

Intended Composition		Analyzed Composition, Wt Pct Ba	Liquidus Temperature, °C
Atomic Pct Ba	Wt Pct Ba		
6	26.5		684
10	38.6	39.32 Ba, 60.32 Mg	703
12	43.5		700
14	47.9		688
16	51.8		684
18	55.35	55.52 Ba, 43.84 Mg	670
19	57.0	56.71 Ba, 43.19 Mg	661
20	58.5	58.06 Ba, 41.60 Mg	645
22	61.4		618
27	67.6		597*

* Eutectic arrest.

The alloys, made up from sublimed magnesium and 99.5 wt pct pure barium, were melted in an Armco-iron crucible in a dynamic argon atmosphere. Thermal analyses were taken using a *Speedomax* automatic recorder. Careful stirring during the solidification process was required in order to avoid segregation. After thermal analysis some of the cast alloys were chemically analyzed. The intended and analyzed compositions of the ten alloys prepared are listed in Table I. Since standard barium determinations cannot differentiate between barium present as element and as oxide, both the barium and magnesium contents of the alloys were analyzed. The fact that the sum of barium and magnesium was close to 100 pct in each case was taken as evidence that no excessive oxidation had occurred.

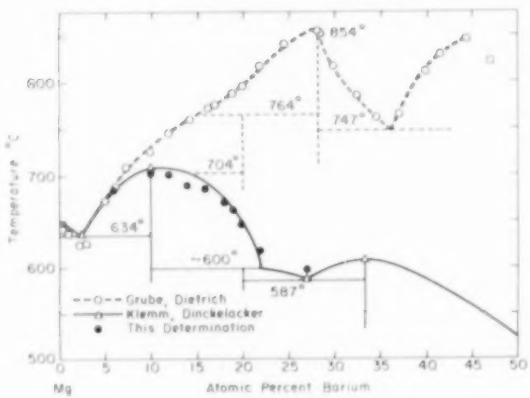

Fig. 1—Liquidus of the system Mg-Ba, comparing the results of Grube and Dietrich, Klemm and Dinckelacker, and the present work.

The liquidus temperatures measured are listed in Table I and plotted in Fig. 1. As can be seen, they are in good agreement with the liquidus found by Klemm and Dinckelacker. This leaves no doubt that the thermal results of Grube and Dietrich above 10 atomic pct Ba are incorrect.

This work was performed under the sponsorship of the Pitman-Dunn Laboratories of Frankford Arsenal, Philadelphia, Contract No. DA-11-022-ORD-1975. Sponsorship and permission to publish by this organization are gratefully acknowledged.

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AIME NEWS

Boston to be Site of 11th Annual New England Regional Conference

The 11th Annual AIME New England Regional Conference will be held on Friday and Saturday May 17 and 18, 1957, at Hotel Statler in Boston. *Melting and Solidification* is the theme of this program, which will be of interest to those working in the science and technology of metals. A session on metals science is planned for Friday morning, with the lead-off talk on *Solidification of Alloys*, followed by talks on *Gases in Metals* and *Principles of Solidification to Grain Refinement of Cast Metals*.

Plant Trips

On Friday afternoon a plant trip will be made to General Electric Co.'s Measurements Laboratory at Lynn, Mass. A social hour will be held between 5 and 6 pm. The annual banquet at Hotel Statler will feature an address by Rev. Daniel J. Linehan, S. J., on *Operation Deep Freeze*. Following the banquet there will be an informal session on personal financial management at which Harry Besse, president of the Boston Stock Exchange, will talk on *Investments, Good and Bad, for the Average Man*.

A metals engineering technical session will be the highlight on Saturday morning, with talks on *Production Vacuum Melting, Single Crystal Production for Transistor Applications*, and *Continuous Casting*. The annual meeting of the Conference Committee will follow a dutch treat luncheon on Saturday.

The Annual New England Regional Conference is sponsored jointly by the Boston and Connecticut Local Sections. Chairman of the Conference is Walter A. Backofen, Assistant Professor, MIT. Also serving on the conference committee are Delmar E. Trout, Scoville Manufacturing Co., Waterbury, Conn., vice-chairman; Donald L. Martin, General Electric Co., Schenectady, secretary; and Sidney Siegal, General Plate Div., Metals & Controls Corp., Attleboro, Mass., treasurer.

(Program below.)

Regional Conference On Reactive Metals Planned For May in Los Angeles

The Second Reactive Metals Conference is scheduled for May 28-29, at the Ambassador Hotel in Los Angeles, under the auspices of the AIME Southern California Section.

In addition to joint sessions, the Metallurgical and Mining Societies will meet separately. There will also be an exhibit of equipment and fabrication techniques prepared by various companies. Featured speaker at the dinner on Tuesday, May 28, is James Boyd, former USBM director, who is now vice president, Kennecott Copper Corp. He will discuss *The Effect of Location of Reactive Metal Resources on the Industrial Development of the U. S.* Bruce S. Old is the guest lecturer at the luncheon, Wednesday afternoon, his topic being *Current Interests in Reactive Metals*.

Registration fee for AIME members is $3.00; all others pay $5.00. Further information may be obtained from B. S. Mesick, general chairman, A. D. Little Inc., 727 W. 7th St., L. A. 17, Calif.

New England Program on Melting and Solidification

Friday, May 17, 1957

9:30 am to 12:00 m—Metals Science Session

Solidification of Alloys: by K. A. Jackson, Harvard University.
Gases in Metals: by C. M. Adams, MIT.
Principles of Solidification and Application to Grain Refinement of Cast Metals: by J. Walker, General Electric Co., Research Laboratory.

12:00 m—Dutch treat lunch

1:30 to 4:30 pm—Field Trip to General Electric Company, Measurements Laboratory, Lynn, Mass.

5:00 pm—Cocktail and social hour

6:00 pm—Banquet

Speaker: Rev. Daniel J. Linehan, S.J.
Operation Deep Freeze

Following the banquet, there will be an informal session on personal financial management at which Mr. Harry Besse, President of the Boston Stock Exchange, will speak on *Investments, Good and Bad, for the Average Man*.

Saturday, May 18, 1957

9:30 am to 12:00 m—Metals Engineering Session

Production Vacuum Melting: by W. W. Dyrkacz, Allegheny Ludlum Steel Corp.
Continuous Casting: speaker to be announced.
Single Crystal Production for Transistor Applications: by B. H. Alexander, CBS-Hytron.

12:00 m—Dutch treat lunch

Followed by the Annual Meeting of the Conference Committee. This meeting is opened to all members of the New England Regional Sections.

AIME Installs Kinzel as President-Elect

Dr. Augustus B. Kinzel of New York was installed as AIME president-Elect, at the Annual Meeting in New Orleans. He will serve as president beginning February 1958. Grover J. Holt, of Ishpeming, Mich., general manager of the ore mining department, The Cleveland-Cliffs Iron Co., became President in 1957.

Dr. Kinzel, vice president in charge of research, Union Carbide & Carbon Corp., was born in New York.

He received a B.A. degree cum laude in math from Columbia University, a B.S. in engineering from MIT, and the degrees of Doctor of Metallurgical Engineering and D.Sc. from the University of Nancy in France. New York University awarded him an honorary Doctor of Engineering degree. Dr. Kinzel has been actively engaged in research with Union Carbide for the past 29 years, and his contributions cover a wide range of activities in the fields of metallurgy, industrial gases, and atomic energy. He pioneered in the theory of stainless steels, was responsible for solving difficulties in the welding and cutting of steel, and has more than 40 patents issued in his name.

A. B. KINZEL

Dr. Kinzel has served as consultant to various AEC installations including Los Alamos, Oak Ridge, Argonne, Knolls Atomic Power, and Brookhaven Laboratories. As a member of the Manhattan District Committee for World Control of Atomic Energy, he helped draft the report that was the working basis for the Lilienthal and Baruch plans.

Coauthor of the Engineering Foundation's volumes on low and high-chromium alloys, Dr. Kinzel has also written more than 60 technical papers on metallurgy and physical chemistry of steelmaking, on ferroalloys, testing and welding of metals, and on applied mechanics. An accomplished linguist, Dr. Kinzel has lectured in many countries abroad.

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Blast Furnace Officers

The Nominating Committee of the AIME Blast Furnace, Coke Oven, and Raw Materials Committee has recommended the election of the following officers for the terms stated: chairman, 1 year, F. M. Hamilton, Jones & Laughlin Steel Corp., Star Lake, N. Y.; vice chairman, 2 years, R. E. Powers, Koppers Co. Inc., Pittsburgh; secretary, 1 year, R. L. Stephenson, U. S. Steel Corp., Monroeville, Pa.; member, executive board, 4 years, E. K. Miller, Jr., U. S. Steel Corp., Gary, Ind.

EJC Report on Income

The Engineers Joint Council report of Professional Income of Engineers—1956, is now available. It is based on figures compiled on about 110,000 engineering graduates employed in industry, government, and education. The data is presented in various graphic and tabular forms, similar to the 1953 report, to facilitate analysis, statistical comparison, and the development of trends. EJC will accept orders for the report, at $1.50 per copy. Write to EJC, 29 W. 39 St., N. Y. 18.

High-Temperature Materials Conference

The Hotel Carter in Cleveland will be the scene of a two-day Conference on High Temperature Materials, April 16-17, sponsored by the AIME Cleveland Section. The High-Temperature Materials Committee of AIME-IMD has cooperated in arranging the technical program.

Topics to be included are: the effects of vacuum melting and testing environment on high temperature properties; classes of materials for use at 1500 F in aircraft, missiles, and nuclear reactors. Among the materials which will be discussed are cobalt-base and nickel-base alloys; refractory metals; cermets and intermetallics; sap type materials; and ceramics.

A fellowship hour followed by dinner is scheduled for Tuesday evening, April 16, at which time Willy Ley will address the group.

Pacific Northwest Regional Conference

Portland, Ore., will play host to the AIME 1957 Pacific Northwest Regional Conference to be held in the Multnomah Hotel, April 11 to 13. Among the outstanding speakers scheduled to address the conferees is AIME President-Elect A. B. Kinzel, vice president of Union Carbide & Carbon Corp., in charge of research. He will be heard at the banquet on Friday, April 12, on the subject of *Research in the New Metallurgy*.

The two field trips on the agenda include a visit to the Oregon Metallurgical Corp., the Bureau of Mines, and a tour of the Portland Owens-Illinois Glass Plant.

Those attending will have an opportunity for socializing at the cocktail party and banquet in the Grand Ballroom of the Multnomah Hotel.

Reno Site of Mineral Industry Conference

Co-sponsored by AIME Local Sections in Nevada, Southern California, and San Francisco, the First Pacific Southwest Mineral Industry Conference is slated to be held in Reno on April 5 and 6.

In addition to four technical sessions the first day, two field trips are planned for April 6. One will be to Eagle-Picher Co., and to the open pit gypsum mine and board plant of U. S. Gypsum Co. The second trip will take participants to Anaconda Co.'s copper mine and plant at Weed Heights. A full schedule of social events includes a cocktail party and dinner, while the ladies have a treat in store for them in the form of a smorgasbord luncheon.

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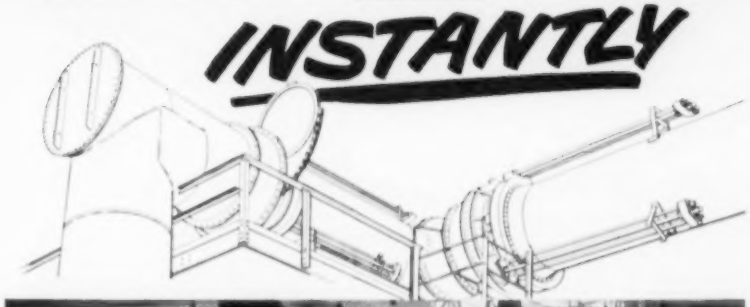

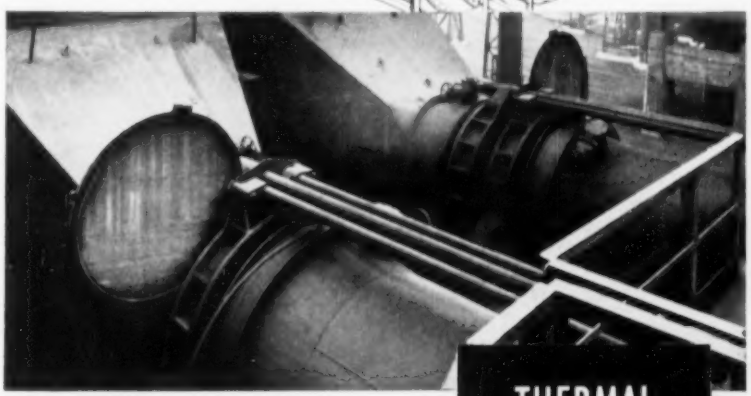

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N.Y. Section Increases WAAIME Scholarships

The AIME Executive Committee has approved the transfer of $3000 from the funds of the New York Section to the educational fund of the Woman's Auxiliary of the Institute. The money will provide for one New York Section Scholarship for undergraduate study in any field covered by the mining, metals or petroleum branches of AIME. The scholarship will be awarded for use at any college or university granting degrees in these fields as long as the curriculum leads to the degree and has the approval of the Engineers' Council for Professional Development.

The recipient is to be selected by the WAAIME, from those applying from any of the 48 states.

New Hampshire Site Of Research Conferences

The Gordon Research Conferences for 1957 will be held June 10 to August 30, at Colby Junior College, New London; New Hampton School, New Hampton; and Kimball Union Academy, Meriden; all located in New Hampshire.

Established to stimulate research in universities, research foundations and industrial laboratories, the conferences consist of scheduled lectures and free discussion groups. Meetings are held mornings and evenings, Monday through Friday, except Fri. evening, while afternoons permit a choice of recreation, reading, or participation in discussion groups. Valuable associations are formed by scientists in related fields which result in cooperative effort between different laboratories. The purpose of the program is to bring experts up to date on the latest developments, to analyze the significance of these developments, and to provoke suggestions as to underlying theories and profitable methods of approach for making new progress.

The conference on *Chemistry and Physics of Metals* scheduled for July 8-12, at Kimball Union Academy will feature sessions on visual observation of dislocations; irradiation effects; and a panel discussion on interaction between point defects and dislocations. A. S. Nowick is conference chairman, and E. S. Machlin, vice chairman.

Conference Theme

Metals at High Temperatures is the theme of the conference to be held June 17-21, at the New Hampton School, under the chairmanship of Nicholas J. Grant. John Frye is vice chairman. Some of the subjects to be discussed are: theories of creep; void formations in reactor materials and in oxidation; theories of dispersion hardening, and multiphase alloy systems.

Accommodations are available for a limited number of women to attend each conference, also for wives who wish to accompany their husbands. All such requests should be made at the time of application, because these accommodations will be assigned in the order received. For applications or further information write to W. George Parks, Director, Dept. of Chemistry, University of Rhode Island, Kingston. After June 10, address mail to Colby Junior College, New London, N. H.

Send Coupon For New AIME Directory

During the month of June, a new all-Institute Directory will be issued. This publication will contain an alphabetical and geographical Company listing of all members on the Institute records, Feb. 1, 1957.

The Directory will be mailed only to those members in good standing who request it by filling out and mailing the coupon below. Each request for the Directory must be made with the coupon. Subsequent announcements will be made concerning the Directory, but the coupon appearing in this issue of the magazine will be the only valid requisition for the book. Fill in the coupon and mail to AIME, 29 West 39th St., New York 18, N. Y.

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Dr. Robert F. Mehl, left, is shown receiving the Grand Medal Le Chatelier, the highest award given by the French Society of Metallurgy in Paris. The presentation was made by Baron Walckenaer, right, president of the Society. Prof. Mehl, director of Metals Research Laboratory, Carnegie Institute of Technology, was honored for his three-fold contribution: scientific work, influence on industry and his role as an educator.

Around the Sections

• The **Washington, D. C. Section** met on March 9 at the Cosmos Club for cocktails and dinner. Guest speaker was Samuel Epstein, technical adviser to the research department, Bethelehem Steel Co., Bethlehem, Pa. Mr. Epstein discussed recent advances in the metallurgy of steel.

Wives of Section members are invited to join the Woman's Auxiliary which holds a luncheon and meeting the second Tuesday of each month at the Broadmoor Hotel.

• The **Detroit Section** held a joint meeting with the Powder Metals Group on Feb. 18, at the Rackham Building. Under the direction of technical chairman W. A. Reich, a program on pressure-density relationships in the pressing of metal powders was held. Guest speaker was W. D. Jones, director, Powder Metallurgy Ltd., London, England. Dr. Jones, who has traveled extensively in Europe and the U. S. is also the author of *Powder Metallurgy*. In his historical approach to the subject, Dr. Jones compared the pressing of metal powders with pressing of solid metals, limiting his discussion to the simple ductile materials such as copper and iron.

• The **St. Louis Section** held a joint meeting with the NOHC Southwest Section on Feb. 8, at the Lennox Hotel. Guest speaker at the afternoon session, Joseph K. Stone, Jr., discussed *The Oxygen Converter Process in Steelmaking Operation and Economics*. Mr. Stone, metallurgist, Steel Plants Div., Kaiser Engineers, Oakland, Calif., gave details of the new development in steelmaking imported from Sweden, the Kal-Do Process, now used by two U. S. companies. He stressed the advantages of the new system which produces high quality steel at lower cost, controls the retention of carbon in the steel, and saves scrap iron by use of iron ore to cool the bath. After the technical session, members enjoyed a cocktail party and dinner.

• When the **Pittsburgh Section** met on January 17, at Carnegie Institute of Technology, guest speaker was W. A. Tiller, of Westinghouse Electric Research Laboratories. Dr. Tiller addressed the group on the subject of *Solute Segregation During Solidification*. A pre-meeting dinner took place at the Schenley Restaurant, and the $4.00 fee included free drinks at the cocktail hour. The Section's Iron & Steel Div. will hold their annual dinner on March 28, at which time Dr. Bruce S. Old, vice president of Arthur D. Little Inc., will speak on *Direct Reduction Processes for the Steel Industry*.

(Continued on page 621)

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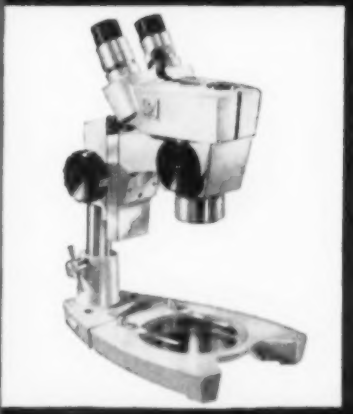

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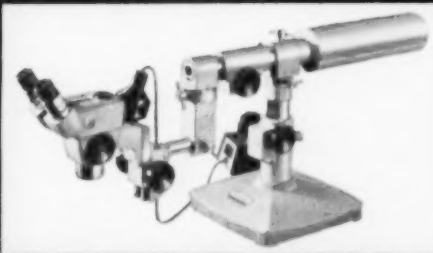

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(Continued from page 535)

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Chemist-Analyst, young, with nonferrous metals experience, with some knowledge of and experience in spectrographic analysis, for well equipped laboratory. Salary, open. Location, Brooklyn. W4633.

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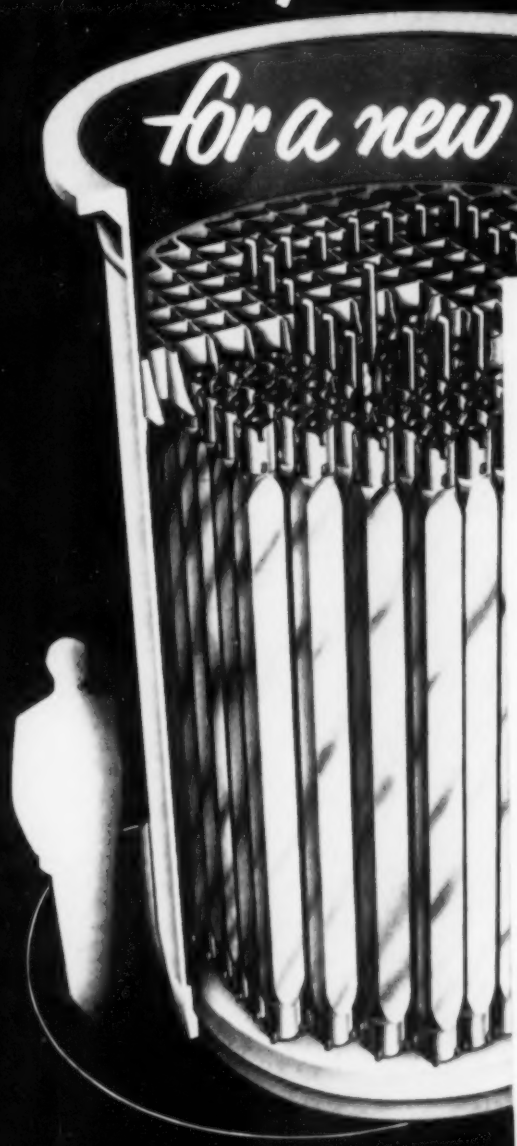

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1956 BLAST FURNACE PROCEEDINGS VOL. 15

The Proceedings of the 1956 Conference of the Blast Furnace, Coke Oven, and Raw Materials Committee, Iron and Steel Division, AIME, can be purchased by those unable to attend the Conference held in Cincinnati, April 9-11, 1956.

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Sizing and Sintering of Ores

Design and Operation of No. 1 Sinter Strand at Jones and Laughlin's Benson Mines. By R. G. Fleck and F. M. Hamilton.

The Lurgi Sintering Plant of the Steel Company of Canada. By T. W. W. Trumper.

Ore Preparation Plant of The Steel Company of Wales Limited—Design, Operation, and Effect on Blast Furnace Performance. By K. C. Sharp and H. R. Tufnail.

Weirton's New Eight-Foot Wide Iron-Ore Sintering Plant. By Julius M. Strassburger.

Blast Furnace Operations

Operating Experiences with High Beneficiated Burdens. By D. Joyce, W. P. Dawhaniuk, and B. Marsden.

The New High-Grade Iron Ores and Agglomerates and Their Effect on Coke Rates. By John Griffen.

Burdening a Blast Furnace for Minimum Costs. By David R. Bailey.

Comparison of Blast Furnace Penetration with Model Studies. By J. B. Wagstaff and W. H. Holman.

Desulphurization of Hot Metal

Application of Theoretical Principles to Desulphurization in Iron and Steel Making. By John F. Elliott.

Desulphurization with Calcium Cyanamid in Hot Metal Ladles. By G. G. Hatch, G. E. Wagner, and M. Trattler.

Desulphurization of Molten Iron. By J. N. Hornak and E. J. Whittenberger.

Desulphurization of Blast Furnace Iron with Injected Calcium Carbide. By Daniel E. Watkins and J. R. McFarland.

Coal and Coke

Pilot-Scale Coke Ovens—Development and Operation. By R. Tracy Eddinger and John Mitchell.

New Pressure-Recording 18-Inch Test Oven. By R. P. Aikman.

Study of Pressure Relationships in Commercial Coke Ovens. By D. C. Coleman and P. J. Farley.

Low Fuel Rates Obtained with Three-Foot Blast Furnace Using Prepared Ores and Coke-Anthracite Mixtures. By Russell C. Buehl and Miles B. Royer.

Research and Development on Sintering

Reaction Zones in the Iron-Ore Sintering Process (JOURNAL OF METALS Award Paper). By R. D. Burlingame, Gust Bitsianes, and T. L. Joseph.

Sintering Investigations Using Factorial Design Experiments. By T. L. Myron, C. J. Davis, and R. L. Franklin.

Methods for Increasing Production Rate of Flue-Dust Sinter. By E. C. Rudolphy and E. J. Whittenberger.

Sintering Iron Ores and Concentrates at Estaca. By Robert L. Bennett, Robert E. Hagen, and Morris V. Mielke.

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• The **Black Hills Section** has announced the committees for 1957, appointed by chairman Alexander McHugh at the Section meeting on January 10. They are as follows: student director, Paul Gries; membership committee, Edward Jacobson, chairman, and Paul Anderson; program committee, Roger Madsen, chairman, and A. L. Lindgard, and R. Keith Collins.

A New Look at the Nature of the Open-Hearth Process by B. M. Larsen, research supervisor, U. S. Steel Corp., has been published in book form by the AIME National Open Hearth Steel Committee.

Mr. Larsen has endeavored to give a unified analysis of the open-hearth process in relation to the factors that control speed and fuel efficiency. Rate of heat flow in the bath, rate of carbon oxidation, and net heat requirement from fuel in relation to the amount of air oxidation from preheated or leakage air, are treated quantitatively. Mechanisms of downward heat flow and of carbon oxidation in the bath indicate the probable effect of excess oxygen, available immediately above the bath surface, on increased absorption of oxygen from the gas phase.

The analysis indicates that fuel consumption might be reduced to about two million Btu per ton with a charge-to-tap time of about five hours per heat if maximum advantage can be taken of the maintenance of an actively boiling bath with a supply of preheated air above the needs of fuel combustion, made possible in a tight system with maximum regenerative efficiency.

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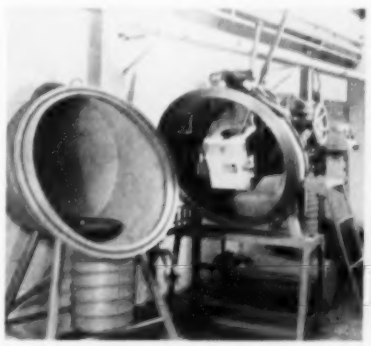

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News From Field of Education:

Scholarships and Courses

Cornell Summer Course

The Cornell Summer laboratory course in techniques and applications of the electron microscope will be given again from June 17-29, 1957, by the department of engineering physics. This summer it will be offered primarily for workers in the fields of physics, chemistry and metallurgy. A session for workers in the biological sciences is scheduled for 1958.

The course is designed to provide an intensive survey of basic theory and interpretation of results. Registration is limited to a small group to assure ample facilities for each student to pursue laboratory work in his special field. The course is under the direction of Professor B. M. Siegel, and further inquiries should be addressed to him at the Dept. of Engineering Physics, Cornell University, Ithaca, N. Y.

Carnegie Scholarships

Carnegie Institute of Technology offers opportunities for advanced study and research in the College of Engineering and Science leading to M.S. and Ph.D. degrees in the following fields: chemical engineering; chemistry; civil, electrical, mechanical and metallurgical engineering; math; and physics.

The announcement for the academic year 1957-1958 includes teaching and research assistantships, and fellowships. Third-time and half-time teaching assistantships are available to graduate students in all departments of the college, the former carrying a stipend of $1200 plus tuition per academic year for the first year, and $1300 plus tuition for the second year. Half-time assistants receive $1500 plus tuition, the first year; $1600 plus tuition the second.

In addition to third-and half-time research assistantships, there are some available full-time to graduate students for the summer months.

Graduate fellowships, supported by outside agencies and special Institute funds, carry grants ranging from $1200-$2500 in addition to tuition. They are offered by most departments of the College to outstanding graduate students, to permit them to devote full time to advanced study and research. The four research laboratories are: Nuclear Research Center, Petroleum, Metals, and Coal Research.

Send applications promptly to Dean of Graduate Studies, Carnegie Institute of Technology, Pittsburgh 13, Pa.

Lead Industries Offer Fellowship in Ceramics

The Lead Industries Assn. is sponsoring a fellowship in the Department of Ceramic Engineering, University of Illinois, for the academic year 1957-1958. The work, research on lead in ceramics, will be under the direction of Prof. A. I. Andrews, head of the department.

The current interest in the low-temperature firing characteristics of ceramics made with lead, has motivated this action by the lead industries, which made a similar grant recently to the School of Ceramics at Rutgers.

Ceramic Engineering Scholarship Increased

The first scholarship-loan fund for students of ceramic engineering, established 1955 at the Missouri School of Mines & Metallurgy, Rolla, Mo., has received an additional gift from donors, J. B. Arthur and family. The fund, named in their honor, is in the form of stock in Mexico Refractories Co., of which Mr. Arthur is president. His recent contribution of 400 shares of stock brings the total to 820. The stock is valued currently at $35 a share. Recipients of the scholarship, who must be in their junior or senior year, receive a $500 grant and a $200 loan for a year.

NYU Lecture Program On Vacuum Metallurgy

The New York University College of Engineering will conduct a program of 25 lectures on vacuum metallurgy June 10-14. Specialists from the U. S. and abroad will discuss vacuum pumping systems, thermodynamics, specific processes, the designs and operation of arc and induction melting systems, as well as applications of vacuum processed materials.

The course is open to persons with a general engineering background including some metallurgy. Inquiries should be addressed to Dr. R. F. Bunshah, New York University College of Engineering, University Heights 53, N. Y.

Co-sponsors are the department of metallurgical engineering and NYU's Office of Special Services to Business and Industry.

PERSONALS

James T. McMullan resigned his position with Atlas Copco Eastern Inc., Paterson, N. J., and is now sales representative for Brunner & Lay Inc., Franklin Park, Ill.

Max J. Kennard has been named chief engineer, Engineering and Construction Div., Southwestern Engineering Co., Los Angeles. He had been vice president in charge of sales and development at Combined Metals Reduction Co., Salt Lake City.

Robert G. Moss has left International Harvester Co., Melrose Park, Ill., to join Westinghouse Atomic Power Div., Bettis Plant, Pittsburgh, as quality control engineer. He recently received a B.S. degree in metallurgical engineering from Illinois Institute of Technology.

Sherrill G. Swenson has completed his studies at the South Dakota School of Mines and Technology in Rapid City, S. D. and is now with the Bethlehem Pacific Coast Steel Corp., Vernon, Calif., where he is metallurgical supervisor for production of wire products.

Elmer Tveter, head of The Dow Chemical Co.'s Mining and Metallurgical Section, has been transferred to Midland, Mich., from Pittsburg, Calif. Also new to the Midland staff are **Robert Kuchinic,** former research assistant, Pennsylvania State University, and **Harry Moulton,** who was a metallurgist with Continental Uranium Co., Grand Junction, Colo.

George V. Bulin, Jr. has joined the Dept. of Geology at the University of Minnesota, Minneapolis.

James F. Peters, retired blast furnace superintendent at Inland Steel Co., E. Chicago, Ind., has a consulting practice in Delray Beach, Fla.

Robert T. Sanden is with Electro Metallurgical Co. in Niagara Falls, N. Y. He had been assistant research metallurgist for the Hanna Coal & Ore Corp., Hibbing, Minn.

O. V. Tally has been appointed manager of the Washington district, Allis-Chalmers Manufacturing Co. A member of the firm since 1926, he had been director of industrial sales of the Industries Group.

Brian P. Canning is assistant metallurgist, American Smelting & Refining Co., Silver Bell, Ariz.

K. Blazewicz has concluded his work at Bisichi Tin Co. in Nigeria and is now metallurgist for St. Patrick's Copper Mines Ltd., Avoca, Ireland.

Charles W. Schlotter is now sales engineer, Wm. H. Taylor & Co. Inc., Allentown, Pa.

THIRD VOLUME

ON

NUCLEAR METALLURGY

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October 8, 1956
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Irradiation Effects on Physical Metallurgical Processes	by Donald E. Thomas
Irradiation Effects in Reactor Materials	by Douglas S. Billington

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The second volume containing six papers presented at the Nuclear Metallurgy Symposium of the Institute of Metals Division, AIME Annual Meeting, New York, February 20, 1956, also can be ordered by mail.

The first volume on "Nuclear Metallurgy" is out of print.

Personals

(Continued from page 623)

D. R. Mathews, chairman of AIME NOHC, has been promoted to general manager, primary production, at Alan Wood Steel Co., Conshohocken, Pa. He had been open hearth superintendent.

William M. Phillips of the Eimco Corp., has been promoted from sales engineer to assistant manager, southern district, Birmingham.

Philip L. Rittenhouse, of the University of Tennessee, has recently been appointed to the staff of Oak Ridge National Laboratory, an atomic energy installation operated by Union Carbide Nuclear Co.

Herbert A. Ball has transferred from Olin Industries, E. Alton, Ill., where he was quality control superintendent, to Olin Mathieson Chemical Corp., New Haven, Conn.

George A. Deitz, metallurgical engineer at Kaiser Aluminum & Chemical Corp., has been transferred from Trentwood Works, Spokane, to the Ravenswood Works in W. Va.

K. K. Ikeuye, Jr. has resigned as metallurgist for the Institute for the Study of Metals, Chicago to accept a position with the Atomic Energy Div., American Standards Assn., Redwood City, Calif.

William Youdelis has been appointed to the Dept. of Metallurgical Engineering, McGill University, Montreal, Canada.

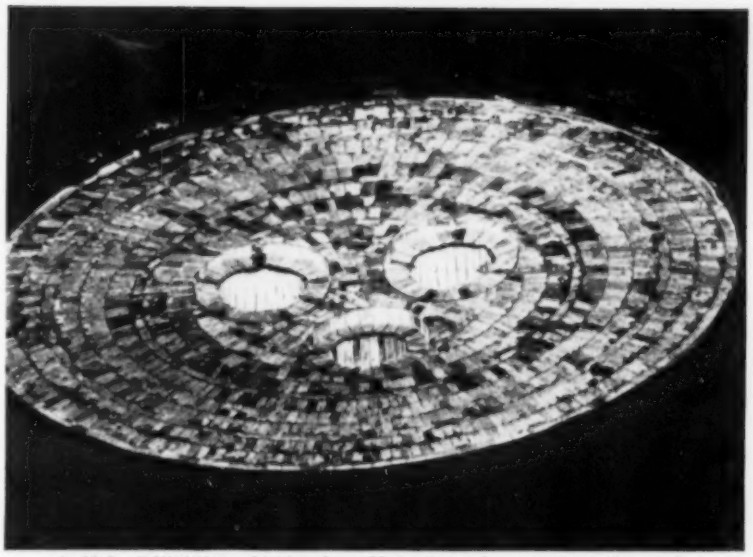
Alfred A. Hendrickson has joined Michigan College of Mining and Technology, Houghton, Mich., as assistant professor of metallurgy. He was formerly physical metallurgist, Ampco Metal Inc., Milwaukee.

Clarence E. Jackson has left Electro Metallurgical Co., Niagara Falls, N. Y., for Linde Air Products Co., Newark, N. J. Both companies are divisions of Union Carbide and Carbon Corp.

Shiro Kohara, formerly at the University of Illinois, Urbana, Ill., has returned to Japan, where he is now on the staff of the Institute of Science and Technology, University of Tokyo.

Robert F. Doelling has been released from active duty in the Navy and is now with St. Joseph Lead Co., Flat River, Mo., with which he was formerly associated.

M. T. Simnad has joined the General Atomic Div., General Dynamics Corp., San Diego. He had formerly been a research associate in the Metals Research Laboratory, Carnegie Institute of Technology, Pittsburgh.



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R. C. COLE

William B. Hall has been elected president and general manager of Vitro Uranium Co., a division of Vitro Corp. of America. At the same time **Richard C. Cole,** assistant general manager, became vice president of the division. Mr. Hall, who joined Vitro in 1951, was named general manager of the uranium division in 1954. He had previously served with Sinclair Refining Co., E. Chicago, Ind., and Southern Oil Co. of Annapolis, Md. Mr. Cole came to Vitro in 1954 after a 19-year association with the American Smelting & Refining Co. He was promoted to assistant general manager the following year.

Robert J. Townsend is enrolled in the University of Connecticut, Storrs, Conn.

Everett H. Belter is currently employed by Bechtel Corp., San Francisco.

Bernard A. Moser has resigned his position as designing engineer, Wilfred L. Roller Co., Pottsville, Pa., to organize his own consulting firm, in the same city.

Mario Signora has resigned his position as director, Research and Control Center, A. F. L. Falck Co., Milan, Italy, to become a director of Breda Siderurgica S.p.A., in the same city.

E. G. Jennings has transferred from Metals & Alloys Ltd., where he was sales vice president, to Ingot Metal Co. Ltd., both in Toronto. His new position is managing director.

Thomas L. Altschuler, former design and development engineer, Semiconductor & Physics Laboratory, Radio Corp. of America, Harrison, N. J., is now employed by General Electric Co. in their advanced electronics center, Ithaca, N. Y.

Frank E. Binns has accepted a job with the nuclear reactor division of Glenn L. Martin Co., Baltimore. He had been associated with the U. S. Air Force.

Bernard Hirst has accepted a position with Taylor Forge & Pipeworks, Gary. He had previously been supervisor of the metallurgical unit, Aircraft Gas Turbine Div., General Electric Co., Cincinnati.

C. A. Zeldin has been transferred from Kennecott Copper Corp.'s Utah Refinery in Garfield, Utah, to the Kennecott Research Center, Salt Lake City, where he will be in charge of project development.

N. S. Covacevich is now assistant general manager of Comercial Euzkadi, S. A., Mexico City, Mexico. He had been serving as general sales manager, La Consolidada, S. A., in that city.

Kenneth W. Palmer has become technical director, Hartford Electric Steel Corp., Conn. He had formerly been chief metallurgist at Pratt & Letchworth, Buffalo, N. Y.

A. D. Gate, former process director, Vanadium Corp. of America, Cambridge, Ohio, has been named technical director of the Beverly Plant, Interlake Iron Corp., Beverly, Ohio.

Paul Dick has joined the staff of General Electric Co., having resigned as physical metallurgist at Frankford Arsenal, Philadelphia.

K. NEUSTAETTER

Kurt Neustaetter has been promoted to superintendent, Plant No. 3 Blast Furnaces, Inland Steel Co., E. Chicago, Ind. He had been assistant superintendent.

Arthur Herbener has joined Electro Metallurgical Co. as sales representative assigned to the Pittsburgh district office. He had been employed by Vanadium Corp. of America as product engineer.

Andrew H. Larson has completed his military service and is presently a graduate student at the Missouri School of Mines and Metallurgy.

Carl B. Post, formerly chief metallurgist, The Carpenter Steel Co., Reading, Pa., is now vice president and technical director of the company.

B. M. LARSEN

B. M. Larsen, formerly research supervisor with U. S. Steel Corp., Kearny, N. J., is now employed by the Edgar C. Bain Laboratory for Fundamental Research, Monroeville, Pa.

George Dubpernell, former manager, Waterbury Laboratories, United Chromium Inc., Waterbury, Conn., has transferred to Detroit, where he has taken a job as technical advisor, Metal & Thermit Corp.

William H. Lenz has accepted a position as supervising physical metallurgist with USBM, Reno, Nev. He had been metallurgical director, Permo Inc., Chicago.

Henry W. Cooper is with Bell Telephone Laboratories, Murray Hill, N. J.

Harry E. Orr has been promoted to commercial vice president at Vanadium Corp. of America, Pittsburgh. He had previously served as assistant vice president in charge of sales.

Peter O. Kirchhoff, formerly metallurgical engineer at Babcock and Wilcox Co., Beaver Falls, Pa., has been appointed technical assistant to the steel mill superintendent.

Franklin H. Wilson has advanced to research metallurgist, The American Brass Co., Waterbury, Conn. He had been an assistant in the research laboratory.

J. H. Follansbee, Jr. has been promoted to sales engineer at the Pennsylvania Transformer Co., Canonsburg, Pa.

Gail L. Stroppel is works manager, The Sawbrook Steel Castings Co., Cincinnati.

C. A. Brassert, formerly president of The Standard Boiler & Plate Iron Co., has become president, Fleet Universal Corp., Pittsburgh.

Edsel E. Bishop has been appointed manager of product development at Wyckoff Steel Co., Ambridge, Pa.

OBITUARIES

Walter C. Haus (Member 1953) died February 3, 1957. He was born on May 2, 1889, in Sharon, Pa. From 1928 until his death, he had served as eastern sales manager of steel plant equipment in the Blaw-Knox Div., the Blaw-Knox Co., Pittsburgh.

NECROLOGY

Date Elected	Name	Date of Death
1917	D. Avery Life Member	October 1956
1951	Samuel J. Beckman	Nov. 16, 1956
1949	John H. Emrick	Unknown
1904	Stephen L. Goodale Legion of Honor	Jan. 17, 1957
1928	James M. Hall	Feb. 4, 1953
1953	Walter C. Haus	Feb. 3, 1957
1908	E. A. Holbrook	Feb. 20, 1957
1928	R. C. Holmes	Unknown
1955	J. D. Phillips	Feb. 27, 1956
1925	George Brown Pryde	Aug. 21, 1956
1920	John Lyon Rich	Unknown
1916	William A. Rigby	Jan. 19, 1957
1940	Willard T. Rogers	July 10, 1956
1945	Edwin B. Royle	Jan. 30, 1957
1956	Edward Scott, Jr.	Nov. 28, 1956
1939	M. I. Signer*	Nov. 17, 1956
1952	F. A. Vandestrick	Unknown

* M. I. Signer was listed incorrectly on the *Necrology* list, February 1957 JOURNAL OF METALS, as M. I. Signer, Jr.

MEMBERSHIP

Proposed for Membership

Metallurgical Society of AIME

Total AIME membership on Jan. 31, 1957, was 26,903; in addition 2,493 Student Associates were enrolled.

ADMISSIONS COMMITTEE

Harold K. Work, Chairman; Francis B. Foley, T. D. Jones, E. S. Machlin, J. H. Scaff, Paul Von Stein, T. B. Winkler.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

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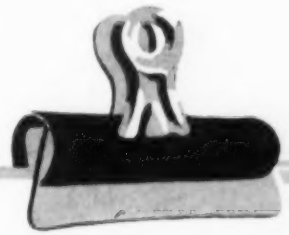

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COMING EVENTS

April 5, 6, AIME, Pacific Southwest Mineral Industry Conference. Sponsor: Nevada Local Section; cosponsors: San Francisco and Southern California Local Sections. Reno.

Apr. 8-10, AIME National Open Hearth Steel and Blast Furnace, Coke Oven, and Raw Materials Conferences, Penn-Sheraton Hotel, Pittsburgh.

Apr. 11-13, AIME, Pacific Northwest Regional Conference, Multnomah Hotel, Portland, Ore.

Apr. 12, AIME, St. Louis Section, dinner meeting East St. Louis; plant trips: Monsanto Chemical Co. Sulphuric Acid plant and American Zinc Co., Monsanto, Ill.

Apr. 16-17, AIME Regional Conference on High Temperature Alloys, Hotel Carter, Cleveland.

Apr. 22-24, CIM, annual meeting, Ottawa, Ont., Canada.

Apr. 24-25, Lead Industries Assn., annual meeting, Drake Hotel, Chicago.

Apr. 25, 26, American Zinc Inst. Inc., 39th annual meeting, Drake Hotel, Chicago.

Apr. 30, Metal Powder Assn., 13th annual meeting, Drake Hotel, Chicago.

May 5-9, American Ceramic Soc., annual meeting, Statler Hotel, Dallas.

May 6, AIME, NOHC Chicago Local Section, spring meeting, Phil Smidt's Restaurant, Chicago.

May 10, AIME, NOHC Eastern Section, plant trip: Colorado Fuel & Iron Corp., Claymont, Del.

May 10-12, AIME, NOHC Western Section, field trip, U. S. Lime Products Corp., Las Vegas, Nev., area.

May 12-10, Electrochemical Soc., Statler Hotel, Washington, D. C.

May 17, 18, AIME New England Regional Conference, 11th annual meeting, Hotel Statler, Boston.

May 20-23, ASME, Design Engineering Conference, Coliseum, New York.

May 28-29, AIME, Reactive Metals Conference. Mining Branch sessions on May 28; Metals Branch sessions on May 28, 29. Ambassador Hotel, Los Angeles.

June 8, AIME, NOHC Southern Ohio Local Section, annual golf party, Middletown, Ohio.

June 23-28, ASTM, annual meeting, Chalfonte-Haddon Hall, Atlantic City, N. J.

Sept. 8-Oct. 9, Commonwealth Mining and Metallurgical Congress, British Columbia to Nova Scotia.

Oct. 6-9, AIME, Petroleum Branch, Dallas.

Oct. 6-10, Electrochemical Soc., Statler Hotel, Buffalo.

Oct. 9-11, Joint Solid Fuels Conference, ASME-AIME Coal Div., Chateau Frontenac, Quebec.

Oct. 18, AIME, NOHC Southern Ohio Local Section, annual meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Oct. 20-Nov. 1, AIME Rocky Mountain Minerals Conference, Denver.

Nov. 4-6, AIME, IMD Fall Meeting, Morrison Hotel, Chicago.

Nov. 13, AIME, NOHC Buffalo Local Section, annual meeting, Hamilton, Ont., Canada.

Dec. 4-6, AIME, 15th Electric Furnace Steel Conference, Penn-Sheraton Hotel, Pittsburgh.

Dec. 8-11, AIChE, annual meeting, Conrad Hilton Hotel, Chicago.

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- **REDUCED LADLE REACTION** — RECARB-X does not cause churning, boiling or other violent ladle reactions. It avoids oxidation of alloys and temperature losses by dissolving quickly and quietly.
- **IDEAL FOR QUALITY STEEL** — RECARB-X is consistently efficient at all carbon levels . . . effective in maintaining maximum rimming action on all high carbon rimmed heats . . . ideal for close carbon specifications.
- **HELPS THE MELTER** — RECARB-X added to the ladle will insure carbon specifications. RECARB-X gives the melter time to finish all heats to proper S, Mn, P, etc. specifications . . . and to tap at the best temperature.
- **SAFE** — no odor or flames to hurt workmen or damage equipment. Light 50-pound bag is easy to toss into the ladle.
- **ECONOMICAL** — RECARB-X is a profit-making investment. Keep your mill schedule. Put more heats into the soaking pit at exact carbon specifications. Make *every* heat count with RECARB-X.

Write for the RECARB-X bulletin today. Get the full facts and arrange a test . . . we will be happy to cooperate.

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